DIET AND AFFINITY FROM THE MIDDLE NEOLITHIC TO EARLY BRONZE AGE, ESTREMADURA, PORTUGAL: A COMPARISON OF HUMAN DENTAL REMAINS FROM FETEIRA II AND BOLORES

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THESIS

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Abstract

The social and political changes accompanying the transition from the Neolithic through Early Bronze Age in southwestern Iberia are reasonably well understood; much less is known about population movements and dietary changes that accompanied these transformations. To address possible population movements and dietary change, human dental remains from the Middle Neolithic through Late Neolithic site of Feteira II (3600-2900 B.C.E) and the Late Neolithic through the Early Bronze Age site of Bolores (2800-1800 B.C.E) will be used to examine diet and affinity. Two hypotheses are tested: the period of social change was associated with dietary change between individuals interred at Feteira II and Bolores and groups interred at these sites are significantly different when observing non-metric dental traits. Microwear features were not significantly different between Feteira II and Bolores, lending evidence that the period of increasing social complexity and long distance interaction did not result in large-scale change in subsistence practices between groups interred at these sites. The investigation of biological distance observing dental morphology between sites determined that they were similar, meaning there was no evidence for population replacement between individuals interred at Feteira II and Bolores.

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CHAPTER ONE

INTRODUCTION

The purpose of this thesis is to asses population movement and dietary changes that may have accompanied the transition from the Neolithic (~5300-3000 B.C.E) through Copper Age/Early Bronze Age (~3000-1500 B.C.E.) in southwestern Iberia. Archaeologically, these time periods are reasonably well understood (Gilman, 1987; Chapman, 1990, 2003; Lillios, 1993; Jorge, 2003); much less is known about population movements and dietary changes that accompanied these transformations (Silva, 2003; Waterman, 2006). From the Middle Neolithic (~4000-3000 B.C.E.) through the Copper Age/Early Bronze Age (~3000-1500 B.C.E.) in central Portugal (Estremadura region) (Figure 1) dramatic social changes were occurring. Fully sedentary agricultural communities were appearing and expanding and large centers such as Leceia and Zambujal were developing from naturally defended cities to walled cities (Sangmeister and Schubart, 1972; Kunst, 1990; Cardoso, 2000). Archaeological evidence suggests that long distance trade expanded, as seen by the appearance of ostrich egg shells and elephant ivory from northwest Africa as well as the appearance of Bell Beaker pottery, found throughout Europe and hypothesized to be brought to these regions by a group of migrants (Childe, 1957; Harrison and Gilman, 1977; Harrison, 1980; Price et al., 2004). All these examples are indicators of increased social complexity.

Did the increase in social complexity leave different biological markers in groups spanning these periods? To address this question, human dental remains from the Middle Neolithic through Late Neolithic site of Feteira II and the Late Neolithic through the

Early Bronze Age site of Bolores were used to examine diet and affinity (Figure 2). Diet is an integral part of culture and social actions throughout human history. A significant change in diet over time could provide biological evidence of social change. Affinity analysis was used to investigate whether groups at Feteira II and Bolores were phenetically continuous, effectively examining whether there is evidence to suggest significant input of foreign genes (e.g. migration) during this time of social change.

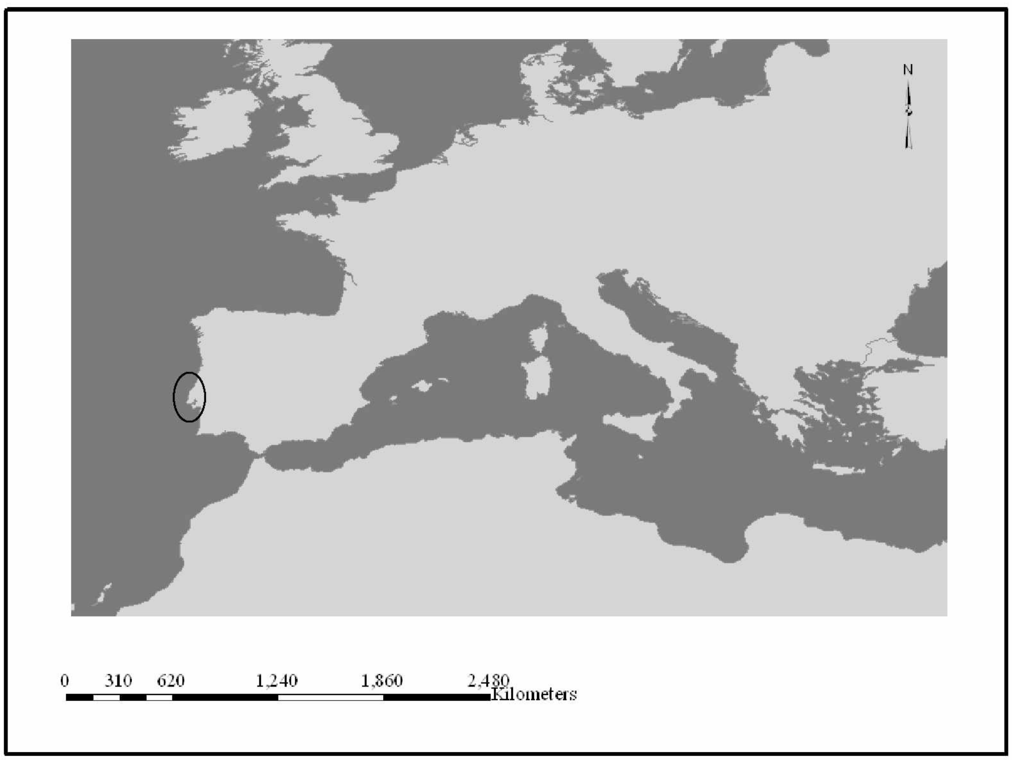


Figure 1. The Estremedura region. This region is indicated by a black circle.

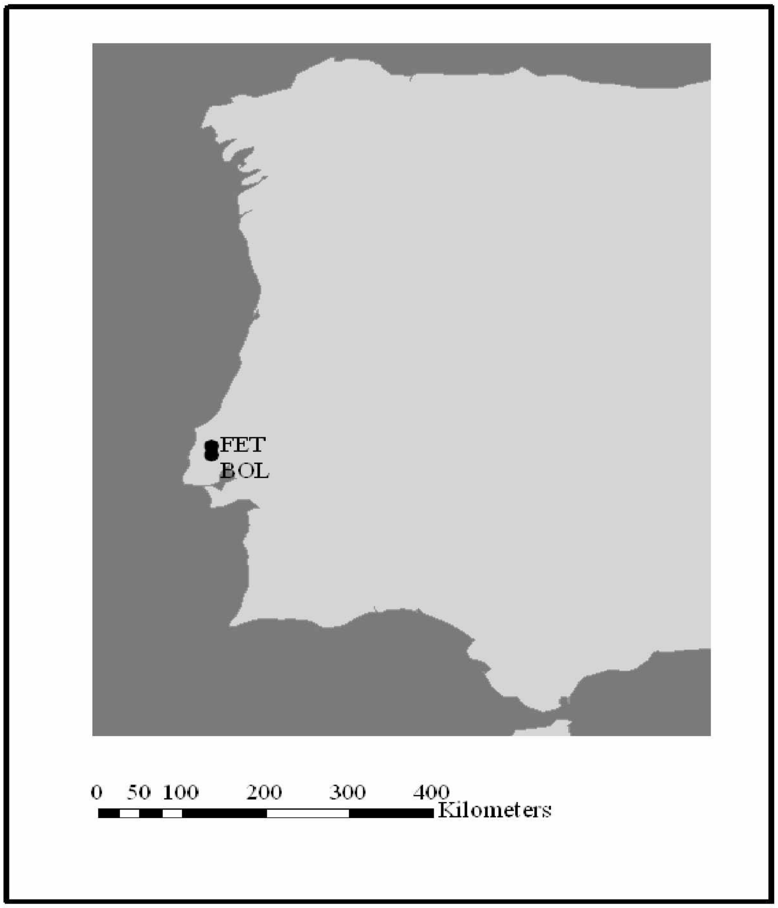


Figure 2. Location of Bolores and Feteira II.

Teeth provide information about ancestry, diet, stress events, genetic disorders, and can be an appropriate location for isotope analysis and DNA collection. The human dentition is integral to the methods used in this and other biological anthropological research for a number of reasons. First, teeth are durable; they can resist taphonomic processes better than other parts of the skeleton and often remain available for analysis when no other part of the human skeleton has survived intact. Second, teeth are covered by a coating of hard enamel that does not remodel like bone Third, teeth have features that are highly heritable and evolve slowly, meaning that over time they are generally unchanging(Scott and Turner, 1988, 1997; Turner et al., 1991; Hillson, 1996, Alt et al., 1998; Irish and Nelson, 2008). Thus, phenotypic indicators such as non-metric dental characters can be used to approximate genetic relationships (Turner et al., 1991; Scott and Turner, 1997; Irish, 2000, 2005, 2006, 2010; Ullinger et al., 2005). To better understand the cultural changes occurring in the Estremadura region, dental microwear and dental morphology have been observed in the dental remains from two burial sites that span this period: the earlier, Feteira II (Middle to Late Neolithic, 3600-2900 B.C.E.) and the later, Bolores (Late Neolithic through Early Bronze Age, 2800-1800 B.C.E.).

Social change has been studied using bioarchaeological methods and specifically, dietary indicators have been used to investigate periods of social and political transformation globally, such as the Mesolithic/Neolithic transition (Smith, 1984; Eshed et al., 2006), culture contact and social rupture (Belcastro et al., 2007), and to compare populations or to describe a single population (Waterman, 2006; Waterman and Horwath, 2009; Herrscher and Le Bras-Goude, 2010; Lillios et al., 2010; Byers et al., 2011). Diet is an integral thread woven in the tapestry of life, essential for survival. As such, dental dietary indicators are integral to the study of diet in the prehistoric past, because teeth directly interact with food and archaeological food evidence is often difficult to find.

Microwear is the study of microscopic wear located on enamel in dentition, and can provide evidence of food texture, food processing techniques, and paramasticatory activities (Hillson, 1996; Larsen, 1997; Teaford, 2007a). Microwear analysis is used to investigate whether dietary change is a significant portion of the social change that occurred at Feteira II and Bolores from the Middle Neolithic through the Early Bronze

Age. By using microwear for this study, it is possible to compare the beginning of the period (Feteira II individuals) and the end of this period (Bolores individuals) to determine if diets between these sites are dissimilar/similar. Dissimilar diets may suggest new groups bringing new food and culture, environment affecting food choice and sources, and/or an increasing reliance on agriculture. Similar diet over time could suggest cultural continuity, meaning that dietary practices were not a significant part of the known increase in social complexity described from archaeological evidence in the Estremadura region of Portugal.

A possible cause of social change at Feteira II and Bolores is immigration, or positive gene flow, into the sites. To test whether significant gene flow accompanied social change, biodistance methods are used to determine affinity between samples. Affinity and biodistance are often examined by observing dental morphology (non-metric dental traits), the study of the variation on the crown and roots of dentition. As dental morphologic traits are highly heritable, they are often used to approximate genetic relationships (Turner et al., 1991; Scott and Turner, 1997; Irish, 2000, 2005, 2006, 2010; Ullinger et al., 2005). As such, to investigate affinity, dental morphology is used to compare individuals from the Middle Neolithic to Late Neolithic site of Feteira II to the individuals from the Late Neolithic to Early Bronze Age site of Bolores. This comparison will address the question of phenotypic continuity across this period of increased social complexity. There were multiple examples of long distance trade in the region; therefore, groups from Bolores and Feteira II will also be compared to 15 samples from northwest Africa, Egypt, Nubia, and elsewhere in the Mediterranean area to identify possible gene flow sources (Guatelli-Steinberg et al., 2001; Irish, 2000, 2005, 2006; Irish and Friedman, 2010). Positive gene flow can greatly affect the culture and biological make up of a population by introducing new genes/people and/or culture; observing dental morphology is one way to investigate if this known increase in social complexity was initiated by the influx of new people/genes.

The Arizona State University Dental Anthropology System (ASUDAS) is the most widespread method used for describing and analyzing dental morphology for a number of reasons: 1) it is well tested and easy to follow, 2) there is a substantial amount of comparative data available worldwide in modern and ancient groups, 3) it is affordable and easy to transport, and 4) it is non-destructive (Scott and Turner, 1988, 1997; Turner et al., 1991; Hillson, 1996, Alt et al., 1998; Irish and Nelson, 2008). The ASUDAS has been used to determine continuity, discontinuity, and affinity in a variety of world populations: the New World (Turner, 1984), India (Lukacs and Hemphill, 1993; Hawkey, 1998; Jonnalagadda et al., 2011), Italy (Cucina et al., 1999), Japan (Higa et al., 2003; Hanihara, 2008) Portugal (Jackes et al., 2001), and Africa (Irish 1993, 1997, 1998a, 1998b, 2000, 2005, 2006; Guatelli-Steinberg et al., 2001; Irish and Guatelli-Steinberg, 2003; Irish and Konigsberg, 2007).

The human remains from Feteira II and Bolores have been submitted to a number of bioarchaeological analyses under the direction of Katina Lillios at the University of Iowa. Since 2006, researchers here have been assembling dental profiles including analyses centered on caries, hypoplasias, carbon and nitrogen isotopes, and macrowear in the two sites (Waterman, 2006, 2012; Waterman and Horwath, 2009, Lillios et al., 2010).

The research presented in this thesis contributes dental microwear and dental morphological data to these profiles, providing a clearer picture of the biological landscape of these burial sites. Microwear and dental morphology as described above have been chosen specifically to address questions, such as affinity, or to provide additional evidence for dietary reconstruction.

Hypothesis and Research Questions

The purpose of this research is to investigate diachronic changes during a period of social change, characterized by the emergence of nucleated settlements, craft specialization, and social inequality, from the Middle Neolithic to Copper Age/Early Bronze Age in the burial sites of Feteira II and Bolores. The following research questions and hypotheses will address biological continuity/discontinuity and dental microwear variation between Feteira II and Bolores.

Research Question-Microwear. Were there dietary differences between Feteira II and Bolores? Previous macrowear analysis suggests no temporal change in diet, while isotope analysis indicates some dietary variability between the peoples of Feteira II and Bolores (Waterman and Horwath, 2009; Waterman, 2012). Dental microwear analysis was used to investigate the conflicting findings between these two analyses. Supporting one or the other of these findings will help to determine if the increase in social complexity was accompanied by dietary change.

Hypothesis One. The period of social change is associated with dietary change between individuals interred at Feteira II and Bolores. Diet can be an indicator of environmental change, social change, and change in health status. Observing diet provides researchers with a direct look into the lives of individuals and groups. In this specific instance, a difference in diet between individuals interred at Bolores and Feteira II could mean that different groups are represented, a selective pressure caused a change in subsistence activities, and/or that novel subsistence patterns were adopted. If there is no difference between these groups pertaining to diet it may speak to the stability of food in the region, as well as similar cultural practices across time.

Research Questions-Dental Morphology. The question of primary importance is: are there dental phenetic differences between the inhabitants of Feteira II and Bolores? Of secondary importance is the question: how do Feteira II and Bolores groups fit when compared phenetically to groups in the Mediterranean area? By looking for phenetic similarities it will be possible to observe locations of potential gene flow that may have affected the Estremadura region during this time period. In addition, the isolation by distance stepping stone model will be used to determine the correlation between phenetic distance and geographic distance (Kimura and Weiss, 1964, Konigsberg, 1990, Irish, 2010).

Hypothesis Two. Individuals interred at Feteira II and Bolores are significantly different phenetically when observing non-metric dental traits. Determining if the inhabitants of Feteira II and Bolores are phenotypically continuous may investigate whether a large-scale population replacement accompanied increased social complexity. If no difference is found between Feteira II and Bolores it would suggest continuity from the Middle Neolithic to the Bronze Age. Continuity would mean that this period of social change was most likely not the result of an influx of new genes/people.

Significance

Although biological anthropologists have contributed to synchronic analyses of prehistoric populations in the Estremadura region, most diachronic studies have focused on the Mesolithic-Neolithic transition (Lubell and Jackes, 1994; Fox, 1996; Jackes et al., 1997a, 1997b; Bamforth et al., 2003; Jackes and Meiklejohn, 2004; Chandler et al., 2005). Dozens of burial sites are known from the Middle Neolithic through the Early Bronze Age, and most bioarchaeological studies of these populations have focused on single site descriptions using multiple methods, or case studies (Silva, 1995, 1999, 2003; Waterman, 2006; Silva and Ferreira, 2008; Neves and Silva, 2010; Lillios et al., 2010). However, biological anthropologists have generally not approached these populations from a diachronic perspective for two primary reasons. First, the Mesolithic-Neolithic transition is often viewed as a more defining moment in the human past than the Neolithic-Early Bronze Age; because of this, biological/demographic studies have been interpreted as more critical. Second, burials of the Late Neolithic-Early Bronze Age were collective and used over a long span of time making it difficult to track biological change within this period. Because the sites selected for this study – Feteira II and Bolores – span different cultural moments in the 4th and 3rd millennia B.C.E., their samples can be studied to elicit preliminary understanding of demography and diet during the emergence of complex societies in the Estremadura.

The research presented here not only addresses biological anthropology; it investigates evidence and hypotheses from archaeology. Synthesizing this research is an important step in understanding the changes occurring in the Estremadura region. Also, this research addresses the major theoretical issue of complexity in the past. Globally, there has been debate as to whether increases in social complexity can be attributed to *in situ* development or migration events (Childe, 1957; Sherratt, 1990; Chapman, 1990, 2003). This research adds to the global understanding of this process during prehistory.

Methodologically, this study contributes dental morphological data to the growing global data set using the Arizona State University Dental Anthropology System. While the global data set includes many samples from Africa and Asia; European groups are less common. Here, dental morphological data from two groups in Portugal will expand the comparative data available for this method.

Thesis Outline

Chapter two reviews geography, environment, archaeology, and bioarchaeology in the Estremadura region of Portugal beginning in the early Mesolithic through the Bronze Age. This chapter summarizes information pertaining to population movements, diet, and settlement patterns.

Chapter three provides a literature review for the two methods used in this thesis: dental non-metrics and dental microwear analysis. These methods are described and studies that are analogous to this research are reviewed. The goal of this chapter is to prove that these are applicable methods to investigate the hypotheses described above.

Chapter four describes the site of Feteira II and Bolores and the groups interred there. The specific methods used by the researcher to investigate the previously mentioned groups will be defined.

Chapter five presents the results of the statistical analysis of dental microwear and morphology. The results of t-tests will be presented to determine whether microwear features are significantly different between Feteira II and Bolores. For dental morphology, frequencies of the dental traits will be summarized and results of the mean measure of divergence (MMD) statistic will be presented. The MMD will be compared to geographic distances to determine if the samples fit the isolation by distance stepping stone model.

Chapter six discusses the results in the context of archaeological and bioarchaeological information already known about the two sites, to provides a synthesis and comparison. Chapter seven provides a brief review and summary of the results and discussion of this thesis. Areas for future research are also identified and described.

CHAPTER TWO

ARCHAEOLOGICAL BACKGROUND

Estremadura Research

A brief overview of lifeways during the Early Mesolithic through the Early Neolithic will be presented below; while the time periods are not directly connected to Feteira II and Bolores, group dynamics that lead up to the use of these locations as burial sites are important. Archaeological and bioarchaeological studies of the Mesolithic period (~11000-5300 B.C.E.) in the Portuguese Estremadura have focused on the following key issues: chronology, reconstructing environmental events that influenced human movement, and finding evidence for population growth (Clark, 2000) (Table 1). Studies of the Mesolithic/Neolithic transition have addressed theories of population replacement, continuity, cultural assimilation, health and dietary changes over the transition, chronology, and demography (Zilhão, 1997, 2000, 2001; Jackes et al., 1997b, Jackes and Meiklejohn, 2004, 2008). Studies of the Late Neolithic (~4000-3000 B.C.E.), Copper (~3000-2000 B.C.E.), and Bronze Ages (~2000-1500 B.C.E.) have focused on settlement abandonment, the role of fortified settlements, social inequality, trade, health, and diet (Chapman 1982,1990, 2003; Gilman, 1987; Lillios, 1993; Jorge, 2003; Waterman, 2006; Lillios et al., 2010) (Table 1).

Table 1. Dates of phases and major events in the Estremadura region (Harrison, 1980; Lillios,1993, 1997; Zilhão, 1993, 2001; Spurk et al., 2002; Schriek et al., 2007; Lillios et al., 2010).

Phase/Event	**Calibrated B.C.E.**
Early Mesolithic	~11000-6200
Late Mesolithic	~6200-5300
Environmental cold event	~6200
Early Neolithic	~5300-4000
Feteira II	~3,600-2900
Middle/Late Neolithic	~4000-3000
Copper (Chalcolithic) Age	~3000-2000
Appearance of Bell Beaker artifacts	~2500-2000
Bolores	~2,800-1800
Settlement Abandonment	~2000
Bronze Age	~2000-1500

There are multiple models of population movement in the Estremadura from the Mesolithic/Neolithic transition through the Bronze Age. The demic-diffusion model suggests the gradual movement of populations from the Near East, spreading agriculture in their wake; farming groups with high population growth replaced or assimilated hunter/gatherer populations (Ammerman and Cavalli-Sforza, 1984; Wells and Geddes, 1986). In contrast, the acculturation model states that Mesolithic groups gradually incorporated agriculture without the input of foreign genes (Whittle, 1996; Zilhão, 1997). The maritime pioneer colonization model states that agriculture came to Iberia by a group of seafaring Mediterranean groups that made stops along the western coast of Iberia, establishing settlements in areas where Mesolithic groups were not present (Zilhão, 1997, 2000, 2001).

There are additional models of population movements during the Copper and Bronze Ages in the Estremadura region. Bell Beaker artifacts have been found throughout Europe and some researchers argue that a specific group of people moved around bringing these artifacts with them. These artifacts include characteristic bell shape containers and other items such as buttons and wrist bands (Childe, 1957; Harrison, 1980; Price et al., 2004; Cardoso et al., 2005). There are two hypotheses related to the appearance of Bell Beaker ceramics in Portugal (Copper Age) (2500-2000 cal. B.C.E.) 1) migration- new people brought the artifacts with them (Childe, 1957; Price et al., 2004), or 2) cultural diffusion- a series of cultural exchanges, instigated by Beaker artifacts being viewed as status symbols, led to widespread dispersal and eventually local production of these artifacts (Harrison, 1980). Historically, there have been two approaches to population movements during the Late Copper and Bronze Ages: 1) Mediterranean colonists/invaders established settlements in the Estremadura and contributed to the social dynamics of the time (Blance 1961; Savory, 1968) or 2) internal group dynamics and developments were the cause of social differentiation, not colonists (Chapman, 1990; Lillios, 1991, 1993).

Chronology of Estremadura

The chronology of the Mesolithic (~11000-5300 B.C.E.) through the Bronze Age (~2000-1500 B.C.E.) in the Estremadura region is based on a large set of radiocarbon dates (Zilhão, 2000, 2001; Cardoso, 2000; Lillios et al., 2010). Calibrated B.C.E. dates will be presented in this thesis, as the majority of dates are reported using this system when referring to the Neolithic (~5300- 4000 B.C.E.) through the Bronze Age (~2000-1500 B.C.E.). There is a new trend for researchers discussing late prehistory in the Estremadura to discontinue using the term Copper Age (~3000-2000 B.C.E.) or Chalcolithic (Gilman, 2000; Lillios et al., 2010). Some archaeologists currently view the

Copper Age (~3000-2000 B.C.E.) as an extension of the Late Neolithic (~4000-3000 B.C.E.) (Lillios, personal communication, 2012), because the occupation of settlements and burials are generally continuous, and the role of metallurgy at this time is small scale. However, the Copper Age will be referred to in this thesis for clarity and comparability with previous research.

Estremadura Geography

As noted, the Estremadura region is located in central Portugal (40°-38°3' Latitude, North) (Bicho, 1993). There are several geographic features that characterize this region: to the north the Mondego River Basin, to the South the Tagus and Sado River Basin, the Atlantic Ocean to the west, and mountainous terrain to the east (Marks et al., 1994). This region has a high amount of geographic variability. The wide river valleys of the Tagus and Sado rivers give way to mountains that rise above 600 m.: the Serra d'Aire, Candeeiros, and Montejunto mountains (Bicho, 1993).The region has wide valleys, and low and high hills (Lillios, 1991). Areas lining the Atlantic Ocean are dominated by high cliffs (Trindade and Ramos-Pereira, 2009).

Mesolithic ~11000-5300 Cal. B.C.E.

Early Mesolithic human groups inhabited the Atlantic Coast of the Estremadura region at sites such as Cabeço do Porto Marinho, Casal Papagio, Bocas I, and Cabeço do Marinho (Bicho, 1994). These sites have flake-rich assemblages with no blades and are often located in open air and cave environments (Clark, 2000; López de Pablo and Puche, 2009). Archaeological studies of the early Mesolithic have generally been restricted to surveys, and most analysis is still at a descriptive stage (Clark, 2000).

During the Late Mesolithic, human habitation sites were located away from the coasts, near estuaries, such as the Muge, Sado, and Tagus Rivers (Zilhão, 1993; Lubell and Jackes, 1994; Bicho, 1994; Clark, 2000; López de Pablo and Puche, 2009). A number of environmental changes instigated settlement pattern changes. Firstly, the limestone massif forests near the coastline became less productive and dense (Zilhão, 2000). Secondly, the 6200 cal. B.C.E. cold event that affected large portions of Europe allowed for a freshwater current to reach the Portuguese coast, reducing upwelling, and resulting in a decline in marine productivity (López de Pablo and Puche, 2009; Bicho et al., 2010). These events, combined, led to the development of year-round habitation sites in the Lower Tagus Estuary (Lubell and Jackes, 1994; López de Pablo and Puche, 2009).

Early Neolithic ~5300-4000 Cal. B.C.E.

The first Neolithic settlements in the Estremadura region of Portugal are characterized by the presence of cardial pottery. Cardial is a type of impressed pottery that has been connected to agricultural communities (Zilhão, 1993, 1997, 2001; Rabe et al., 1997; Jorge, 1999). These sites are located in the area of limestone massifs that contain Upper Paleolithic sites and some early Mesolithic, but no late Mesolithic sites (Zilhão, 2000). Mesolithic groups persisted into the early Neolithic, but were limited to estuary regions (Zilhão, 2001; Chandler et al., 2005). Neolithic settlements were open air, and domestic units unearthed were limited to hut floors and hearths (Rabe et al., 1997). Gruta do Caldeirão is a cave site with no evidence of Mesolithic occupation; collective burials are present with grave goods such as polished stone tools, cardial pottery, and sheep remains; these items are considered to be indicators of an agricultural community (Zilhão, 2000).

Middle to Late Neolithic ~4000-3000 Cal. B.C.E.

The Middle to Late Neolithic and later is of direct importance to this thesis as these periods mark the time of usage for Feteira II (Middle to Late Neolithic) and Bolores (Late Neolithic to Early Bronze Age). Agriculture during this period expanded with evidence of wheat, barley, and legumes, as well as domestication of pigs and cows. Agriculture-related tools, such as sickle blades, storage pits, and vessels were present. Settlements were exclusively open air, and cave habitations were abandoned (Rabe et al., 1997). Craft specialization appeared as well as evidence for long distance trade in the form of ostrich egg shells and ivory from northwest Africa (Harrison and Gilman, 1977). Late Neolithic burials in other areas of Portugal consisted of a large number of megalithic monuments; however, the Estremadura region remained conservative in burial style with cave and rock shelter burials predominating (Jorge, 1999).

Two important settlements that have their roots in the Late Neolithic are Leceia and Zambujal (Sangmeister and Schubart, 1972, 1981; Cardoso, 2000). Leceia is located on a low cliff overlooking Barcarena, a fertile valley about 4 km from the Tagus River. This location boasts natural defenses and access to the valley and river for trade. Zambujal is naturally defended and is also located near an estuary for trade access; its primary function seems to have been as a trade center (Sangmeister and Schubart, 1972, 1981; Kunst, 1990).

Copper Age (Chalcolithic) ~3000-2000 Cal. B.C.E.

During the Copper Age the first completely sedentary and fully agricultural communities flourished in the Estremadura. These communities were characterized by the construction of monumental collective tombs and evidence of social inequalities in the variability of burial types (Lillios, 2004). Settlements expanded to a wide range of geographic locations, and construction during this period was intensive and resulted in an increase in monumental architecture construction (Jorge, 2003). Populations in coastal settlements amassed prestige goods, such as Bell Beaker ceramics, and developed fortifications (Lillios, 1993).

Evidence of long distance trade flourished during this period with an increased number of ostrich eggs shells and ivory from northwest Africa found in Leceia and Zambujal, as well as Beaker pottery present in northwest Africa (Harrison and Gilman, 1977; Diaz-Andreu, 1995; Jorge and Jorge, 1997). Copper Age ivory from Leceia has been sourced to the African Savannah Elephant (*Loxodonta a. africana);* this type of ivory is not present in Spain until the Early Bronze Age (Schuhmacher et al., 2009). Local exchange was also important; flint, copper, and amphibolite objects are plentiful in the Estremadura region; however, no known sources for these resources exist there, indicating that a trade relationship existed between the Alentejo region of Portugal and the Estremadura (Lillios, 1997; Jorge and Jorge, 1997).

Burials continued to be placed in caves and rock shelters and, increasingly, tombs, such as tholoi (corbel vaulted tombs) were used. Grave goods in collective burials changed; engraved plaques made of slate with various etched designs were found in many tombs of the Estremadura and are hypothesized to be genealogical records (Lillios, 2004). Burials from this period have 10-400 individuals that are co-mingled and in a highly fragmentary state (Jorge and Jorge, 1997). Collective burial locations were used, reused, and maintained over generations (Sanjuan, 2006).

Hilltop settlements with natural defensive structures appear during the Copper Age (Gilman, 1987; Lillios, 1993; Jorge and Jorge, 1997). Fortified Copper Age sites continued the trend of maintaining strategic locations connected to estuaries and the sea, with natural defensive characteristics (Jorge, 2003). Leceia, during the Copper Age, was a walled hilltop settlement with a vibrant economy (Cardoso, 2000). Cardoso (2000) reports storage vessels, loom weights, and cheese strainers (evidence of secondary products revolution), as well as remains of sheep, goats, oxen, swine, fishing hooks, mollusks, and evidence of forest clearing activities being found and associated the Copper Age. Zambujal was a walled settlement with bastions and evidence of copper working, textile production, and pottery manufacturing (Sangmeister and Schubart, 1972; Kunst; 1990). The settlement was at the end of a rock promontory, only 1 km from the sea, with drinking water accessibility (Sangmeister and Schubart, 1972; Kunst, 1990). Zambujal's location demonstrates planning because it is in a central trade location and had use of the Sizandro River to the coast (Sangmeister and Schubart, 1972; Jorge and Jorge, 1997).

Bell Beaker ceramics were present from 2500-2000 B.C.E. in central Portugal (Harrison, 1980). Beaker ceramics include distinctive cups, archery, and jet, amber, gold, and bronze items, copper tools, daggers, flint projectile points, and engraved stone plaques (Lillios, 2000; Price et al., 2004; Cardoso et al., 2005). These items appear in most of Europe and have been the center of debate: did new people migrate or were these ceramics part of a cultural exchange? Bell Beaker ceramics are described as characteristic bell-shaped ceramics and have a wide distribution: Hungary, Great Britain, northwest Africa, and much of the Atlantic Coast of Europe (Cardoso, 2000; Cardoso et al., 2005).

There are two general hypotheses for the widespread appearance Bell Beaker artifacts in Europe: 1) Childe (1957) argued that Beaker ceramics were connected to a migrating group and 2) Harrison (1980) argued that Beaker ceramics were status symbols, highly desired objects, spread throughout Europe through cultural interaction or diffusion. Price et al. (2004) investigated the migration and diffusion debate surrounding Bell-Beaker ceramics using strontium stable isotope analysis on individuals found in Austria, Hungry, and the Czech Republic. Price et al. (2004) concluded that there was evidence for large-scale migration in south-central Europe in association with Bell-Beaker artifacts. Is there evidence for migrations in the Estremadura region in association with the Bell Beaker period (2500-2000 B.C.E.) (Harrison, 1980; Price et al., 2004)? Fleure and Peake (1930) suggested that Beaker ceramics were standardized in Central Europe and through a series of long term cultural contacts made their way to the Iberian Peninsula. Cardoso et al. (2005) studied the style and composition of Beakers found at four Copper Age sites in the Estremadura, including Leceia, to determine if there was a connection between the styles and composition of Brittany and Portugal. Using thin section analysis Cordoso et al. (2005) found no evidence for a connection between Brittany and the Bell Beakers of Leciea beyond similarity in style. If Bell Beaker ceramics were brought to the region by "Beaker Folk" these migrants may have contributed to cultural and biological change in the Estremadura region of Portugal.

At approximately 2000 B.C.E., during the transition to the Bronze Age, there was a period of settlement abandonment in Estremadura (Gilman, 1987; Chapman, 1990, 1995, 2003; Lillios, 1991, 1993; Lillios et al., 2010). Fortified Copper Age sites were abandoned for new unfortified sites, long distance trade dissolved, and burials shifted to individual graves, which involved lower energy investment (Lillios et al., 2010). A series of palynological studies were carried out in the Estremadura and Algarve regions as well as in S-W Spain. This work revealed evidence of viticulture, the creation of pasture lands, and a decline of regional forests (Leeuwaarden and Janssen, 1985; Stevenson and Moore, 1988; Stevenson and Harrison, 1992; Fletcher et al., 2007; Vis et al., 2010). Further, these studies provide support that ecological degradation could have influenced settlement abandonment and in part caused group division in the Estremadura (Lillios 1991, 1993; Lillios et al., 2010). This hypothesis is supported by evidence of environmental change, competition, and comparisons with groups that are known to divide (Lillios, 1991). It has also been suggested that an invading force may have destroyed settlements and driven residents to leave, replacing the original groups with groups of Mediterranean origin (Blance, 1961; Savory, 1968); however, these arguments have largely been dismissed due to the evidence described above.

Early Bronze Age ~ 2000-1500 Cal. B.C.E.

Bronze Age sites are difficult to locate because the dense hilltop settlements characteristic of the Copper Age gave way to more dispersed habitations (Lillios, 1991, 1993). The settlements that did exist exhibit a sharp decline in the number of long distance goods. Trade was minimal until the end of the Bronze Age when there was a major influence from Mediterranean groups on construction and cultural items (Diaz-Andreu, 1995).

Funerary shifts accompanied this chaotic period. Cave burials became less common and there was a decline in the amount of prestige goods with burials. Individual internment became widespread and less energy was invested in grave construction (Sanjuan, 2006). This trend continued throughout the Bronze Age until funerary areas were largely unobservable on the landscape.

Bioarchaeology in Portugal

Studies of Diet. Previous bioarchaeological studies of diet in Portugal, specifically in the Estremadura region, addressed the Mesolithic/Neolithic transition, and general dietary trends. Lubell and Jackes (1994) were the first to study dietary change between the Mesolithic and Neolithic in the Estremadura (and Alentejo). Through analysis of nitrogen and carbon stable isotopes, rates and types of macrowear, and dental caries analysis; they concluded that a significant portion of the Mesolithic diet consisted of marine resources. Over time, however, terrestrial resources were exploited, and the Neolithic was characterized by a diet influenced by terrestrial animals and C_3 plants (Lubell and Jackes, 1994:213). Their study of macrowear indicated that the rate of wear decreased and the appearance changed from flat to cupped (Lubell and Jackes, 1994:210). Cupped wear is indicative of technology for grain grinding or the inclusion of grit, such as sand, during mastication (Smith, 1984). The number of caries were variable in Mesolithic and

Neolithic populations, as some groups within each phase had significantly higher caries frequencies; however, in general, caries rates increased (Lubell and Jackes, 1994).

Fox and Martin (1999) analyzed the occurrence of caries in the inhabitants of Iberia from the Mesolithic to present to track dietary shifts. They observed 34 samples, most with a sample size of 20 or more, spanning 8,000 years. This study concluded that caries were present in Mesolithic contexts at moderate and high rates compared to those in hunter/gatherer groups globally. The increased frequency of lesions is related to the inclusion of high sugar fruits and wild honey in the Mesolithic diet (Cunha and Cardoso, 2001).

More recently, Jackes (2009) compared Mesolithic primary burials at the Moito (MNI of 85) and Cabeço da Arruda (MNI of 105) Tagus River middens in the Estremadura with Neolithic sites for frequency of dental caries. Her ultimate goal was to investigate a change in subsistence during the Mesolithic/Neolithic transition. She concluded that dental pathology was complex over this period and no simple increase in caries frequency could be detected.

Waterman (2006) investigated caries frequency at the site of Feteira II (n= 68) in the Torres Vedras region of the Estremadura. 7.88% of teeth, in this Middle to Late Neolithic site, had caries (Waterman, 2006: 48). When compared to other contemporaneous sites (Casa de Moura,Poço Velho, São Padro de Estoril I, Pai Mogo I, Cabeço da Arruda I, and Cova da Moura), she found evidence that health improved as social complexity increased.

The study of caries frequencies in the Estremadura is problematic. Caries frequencies throughout the Mesolithic and Neolithic are highly variable, with Mesolithic levels being higher than anticipated in some cases because of the inclusion of sugar rich fruits or honey in the diet (Cunha and Cardoso, 2001).

Study of Population Continuity. Jackes et al. (2001) used non-metric dental traits to assess the affinity and biological continuity of populations over the Mesolithic, Neolithic and Bronze Ages from western Iberia. Samples were included from the Iberian sites of Cova da Moura, Dolman junto à Estrada de Ansião, Palmogo I, Monte Canelas I, Hipogeu do São Paulo, and Colmbra were compared to nine North African samples and two Iroquoian samples. They specifically tested for phenotypic continuity, using seven traits to determine that there was no significant difference between Mesolithic and Neolithic groups. The use of multidimensional scaling revealed that the Portuguese samples did not cluster in any specific pattern.

Archaeological Background of Feteira II and Bolores

Feteira II. Feteira (I and II) is a cave burial located in the Estremadura (39°16’46.0986” N and 9°16’4.5906” W (Figure 3) (Zilhão, 1984; Waterman, 2006). Feteira I was first excavated in 1982 by João Zilhão, to salvage archaeological material discovered during a construction operation. Feteira II, the site studied for this thesis, was later discovered in another portion of the cave that contained a number of human remains. Cidalia Duarte excavated Feteira II during three summer seasons from 1995-1997. The site has been radiocarbon dated to 3600-2900 cal. B.C.E. Most Feteira II excavations took place in the main gallery -- measuring 13 by 1.3 meters. The burial area is set apart from the rest of the area by a series of limestone boulders with commingled burials lining the cave wall; approximately 68 individuals were unearthed (Cedalia Duarte, unpublished data; Waterman, 2006).

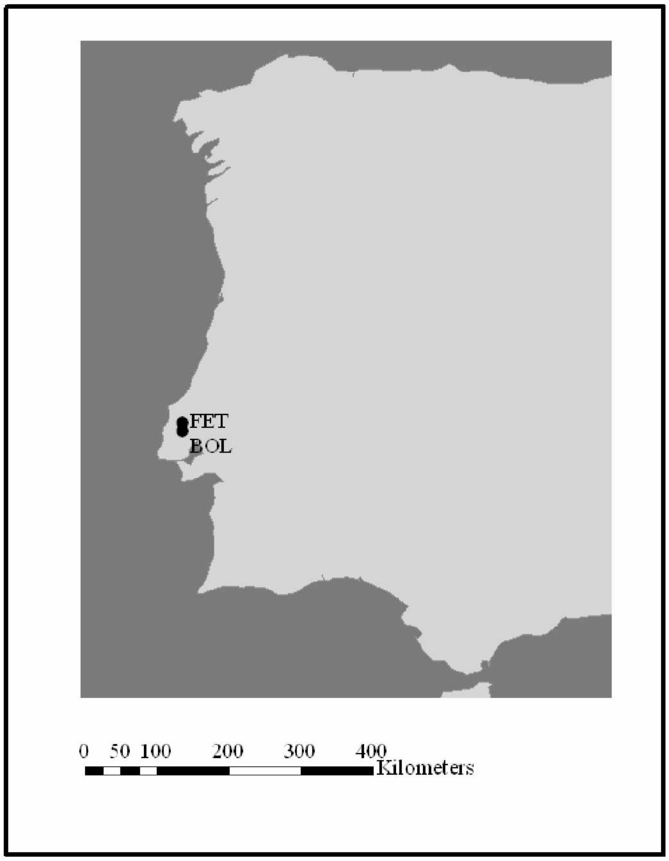


Figure 3. Location of Feteira II (FET) and Bolores (BOL).

Three separate deposition layers are reported: A, B, and C. Radiocarbons dates were calculated from layers A and B. Layer C is assumed to be the oldest, and is set apart from the rest by an *in situ* burial. This burial was partially articulated and, flexed, and found with an inverted *Pectin maximus* shell. Twenty four human teeth were recovered from this layer all *in situ*. The earliest (un-calibrated) radiocarbon date for layer B is 4760

+/-60 B.P. It is characterized by commingled and disarticulated skeletal remains and contains the most human remains. Two hundred and fourteen human teeth were discovered from layer B, 187 were isolated and 27 were *in situ*. Layer A is the most recent layer (4370 +/- 40 B.P.). It is similar to B, as it too is characterized by intermixed and disarticulated skeletal remains. Six hundred and fifty eight isolated teeth and sixty eight *in situ* teeth were excavated from layer A. Approximately 504 isolated teeth and 71 *in situ* teeth were not associated with a specific layer. Similar artifacts were unearthed in all layers, including a total of 24 projectile points, 283 beads, and sherds from a Bronze Age intrusive vase (Waterman, 2006).

Feteira II has been dated to the Middle to Late Neolithic. A range of bioarchaeological analyses were conducted on the human remains from Feteira II (Waterman, 2006; Waterman and Horwath, 2009). Waterman (2006) investigated the remains to assess health status, and compared the data to other samples in the region. Analysis of caries rates, age-at-death, attrition, and enamel hypoplasias determined that there was no evidence of declining health as social complexity increased from the Neolithic through the Copper Age. Attrition rates were consistent with prehistoric agricultural groups. Approximately one third of the teeth are within Smith's (1984) (Appendix A) score one range; the next highest scores were two and three, and very few reached the highest seven-eight range. However, of teeth with the most attrition, there was a prevalence of cupped wear that is common in prehistoric agricultural groups (Smith, 1984). Hypoplasias were present in 6.69% of the teeth, primarily canines, which may correlate with weaning stress. Almost two-thirds of the hypoplasias were formed while the individual was between the age of three and five. Caries were present in 7.88% of teeth (114 teeth out of 1446), and only two deciduous teeth were carious (Waterman, 2006:35). Nitrogen and carbon isotope data revealed that individuals from Feteira II ate primarily C^3 plants and terrestrial proteins; however, there was evidence that some individuals consumed marine proteins and C^4 plants most likely millet or seaweed (Waterman, personal communication, 2012).

Waterman and Horwath (2009) compared attrition rates of Feteira II and Bolores using the methods outlined in both Smith (1984) (Appendix A) and Molnar (1971) (Appendix B). Bolores teeth exhibit a slightly higher average score of 3.81; Feteira II is 3.78. The angle of wear indicates of a reverse curve of Monson and suggests a gritty, abrasive diet. Because wear patterns and scores were similar, it was concluded that there were similar diets between the Middle to Late Neolithic and Late Neolithic to Early Bronze Age. Lingual surface attrition of the maxillary anterior teeth (Turner and Machado, 1983; Irish and Turner, 1987, 1997) was observed on the maxillary central incisors, and unusually angled wear is present on some mandibular molars – which suggests paramasticatory activities (Waterman and Horwath, 2009).

Bolores. Bolores is an east-facing artificial rock-shelter burial site (39°05'32.17" N and 9°17'28.64" W), located on Jurassic sandstone and shale outcrop. It was used from 2,800 to 1,800 cal. B.C.E., as established by four AMS radio-carbon dates (Figure 3) (Lillios et al., 2010). The University of Iowa team, over four field seasons (1986, 2007, 2008, 2010), recovered approximately 2,000 human bone fragments. The excavation of Bolores was part of the Sizandro and Alcabrichal Research Project, a collaboration between the

German Archaeological Institute-Madrid and University of Iowa. Local farmers discovered the site in 1986 while clearing land for a new vineyard; at that time, they unearthed human bones and artifacts, including flint blades, ceramics, and limestone idols typical of the Late Neolithic/Copper Age (Kunst and Trindade 1990; Lillios et al., 2010). The site was filled with sediment and large stone slabs from a roof collapse (Zilhão, 1987).

Bolores is approximately 10 km from the Atlantic Coast, 2 km from the contemporaneous walled settlement of Zambujal, and 2 km from a marine estuary associated with the Sizandro River. The rock-shelter is 5.5m long, 1.5m deep and 1m high; roof and walls are comprised of sandstone, and the floor is dark grey shale. Excavations by the University of Iowa team revealed several ceramic sherds, nine beads made of either shell, limestone, or shale, a quartzite 'bola', a bone handle, a flint blade, and red and yellow ochre. Human remains are located between the roof collapse and shale floor in a bone bed deposit 20-30 cm thick. A minimum number of 22 individuals were recovered (11 adults, 11 sub-adults). There are 8 children age 0-10, 3 adolescents 10-21, 8 adults young to middle aged, and 3 adults 45+ (Waterman, personal communication, 2011). The human remains are highly fragmentary; those located under the roof fall were crushed *in situ;* those away from the fall are better preserved. Teeth are one of the best preserved elements at the site (Lillios et al., 2010).

Multiple bioarchaeological techniques where employed to investigate the human remains at Bolores (Waterman and Horwath, 2009; Lillios et al., 2010). In general, pathology rates are low. There is no cribra obitalia or porotic hyperostosis and only mild osteoarthritis. Dental caries are present in 1.86% of teeth, and in 2 of 14 individuals or about 14% of the sample. Hypoplasias occur in 5.6% of teeth and are present in 3 of 14 individuals, or 21% of the sample. Nitrogen and carbon isotope analysis indicate that three adults had a diet of C^3 plants and terrestrial protein, while one sub-adult was slightly divergent (though still fell in the C^3 plants and terrestrial protein scores). Attrition scores are low because this site has a large number children and adolescents who generally have less wear than adults; the average score for first and second molars using Smith's scale is 3.81 (Waterman and Horwath, 2009; Lillios et al., 2010).

CHAPTER 3

METHODS BACKGROUND

Bioarchaeology

Data in bioarchaeology can be used to test hypotheses of population movements, health, diet, demography, and social interactions (Larsen, 1997, 2002). Researchers examine population movements by observing, among others, aDNA (O'Rourke et al., 2000), oxygen (White et al., 1998) and strontium isotopic evidence (Price et al., 2004), and non-metric dental traits (Scott and Turner, 1997). Evidence for population health is found in the bioarchaeological record: skeletal effects of anemia (porotic hyperostosis and cribra orbitalia) (Stuart-Macadam, 1989), non-genetically induced enamel hypoplasia (Sarnat and Schour, 1941; Goodman and Rose, 1990), dental caries (Larsen, 1983; Jackes et al., 1997a, 1997b), periostitis and osteomyelitis (Schultz et al.,2007), and osteological signs of treponematosis (Baker et al., 1988), tuberculosis, and leprosy (Buikstra, 1976; Larsen, 2002, 1997). Demographic studies use a variety of statistical methods to reconstruct paleodemographic variables such as mortality, morbidity, and fertility (Jackes and Meiklejohn, 2008). Social interaction can be inferred through trauma and evidence of violent death (Lovell, 1997; Larsen, 1997; Walker, 2001). Lines of evidence that explore diet are: dental caries (Larsen, 1983; Gamza and Irish, 2010), stable isotope and trace element analysis analysis (Richards and Hedges, 1999), dental macrowear (Smith, 1984), and dental microwear (Teaford and Runestad, 1992; Ungar, 1996; El-Zaatari, 2008). This study uses bioarchaeological methods, specifically microwear and dental morphology, to investigate diachronic change.

Dental Anthropology

Teeth are important sources of information because they are abundant in the archaeological record, durable, and are observable in living and deceased populations (Scott and Turner; 1997). Researchers studying dental anthropology can address a wide spectrum of topics: health, affinity, population movements, diet, paramasticatory activities, age-at-death, and minimum number of individuals in a site. Techniques used to address these topics are: stable isotope analysis, ancient DNA analysis, dental microwear and macrowear, defects in structure, dental disease, and metric and non-metric dental variation (Larsen, 1983; Scott and Turner, 1988; Cavalli-Sforza et al., 1994; Scott and Turner 1997; Hillson, 1996; Price et al., 2004).

Microwear

Dental microwear is microscopic abrasion or attrition on the enamel surface of human, animal, and fossil teeth (Teaford et al., 1996). Studies of dental microwear have been used to investigate diets in humans, animals, fossil primates, and hominids (Gordon, 1982; Covert and Kay, 1981; Teaford and Oyen, 1989; Bullington, 1991; Teaford and Runestead, 1992; Ungar 1996; Ungar and Teaford, 1996; Rafferty et al., 2002; Grine et al., 2006; Ungar et al., 2006; Greene, 2006; Estebaranz et al., 2009; Gamza and Irish, 2010; Gamza, 2010). The relationship between diet and microwear begins with the chewing cycle, where tooth on food and tooth on tooth contact occurs.

The Chewing Cycle and Wear Facets. The chewing cycle is an integral part of the formation of dental wear facets – which are used in the comparison of microwear features. The chewing cycle in primates has three phases: the closing stroke, the power stroke, and the opening stroke and occurs in one side of the mouth (Kay and Hiiaeme, 1974). In the closing stroke, cusp tips meet by closing the jaw from maximum gape, a shearing movement. The power stroke is further delineated into two distinctions. During phase I of the power stroke, molar cusps slide and result in centric occlusion, meaning that the buccal portion of the lower molar and the lingual portion of the upper molar are in contact (Kay and Hiiaeme, 1974). During phase II of the power stroke grinding occurs by the buccal and lingual portions of the lower and upper molar being brought together. The opening stroke is the final phase of the chewing cycle. During this phase the mandible is once again opened to maximum gape (Kay and Hiiaeme, 1974).

Phase II facets are named 10n, x, and 9 and phase I facets are 1-4 on the buccal region and 5-8 on the lingual region of dentition (Gordon, 1984). During phase II, food is located between the upper and lower molars as the protocone and hypoconid move against one another (Kay and Hiimae, 1974). This interaction between food and the phase II facets leave characteristic microwear features, such as pits and scratches that can be quantified. Because of this interaction, facets formed during phase II of the power stroke are the most commonly used facets in primate microwear studies (Krueger et al., 2008).

Microwear Features. Clearly, microwear is formed by the direct interaction of food and teeth. This interaction causes specific features to be formed. These features can be used to draw conclusions about diet in human populations. Ratios of pits and scratches are used to investigate dietary change or to reconstruct diets in groups. Microwear studies are able to reconstruct mandible movements, the chewing cycle, and components of diet; such as dietary texture, based on frequency of microscopic pits, scratches, and polishing (Figure 4) (Molleson et al., 1993; Hillson, 1996).

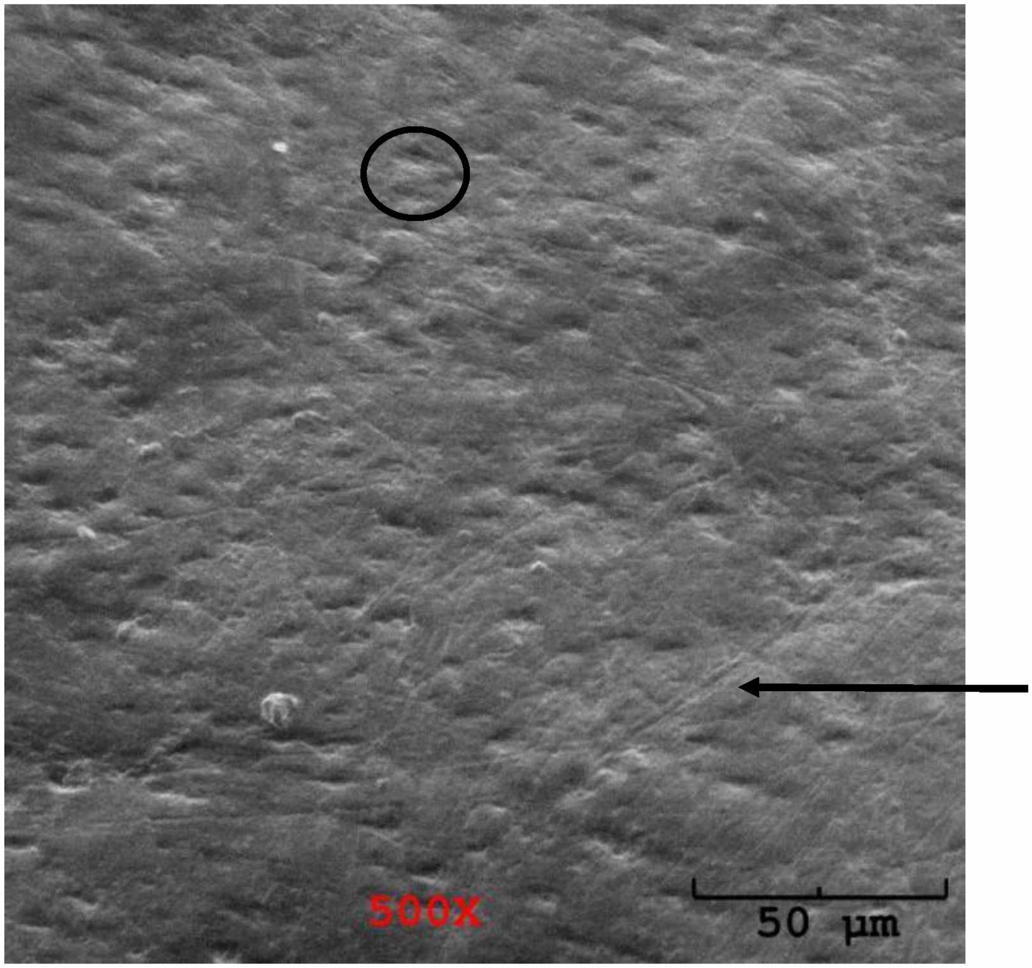


Figure 4. Scratches and pits on human dentition (500x). Scratches are indicated by arrow and pit indicated by circle.

There are four types of wear that influence microwear features: attrition, abrasion, sliding wear, and erosion. Attrition is cause by tooth-on-tooth contact and generally produces polished surfaces and long parallel scratches. Abrasion is caused by tooth-on-food or particles and generally causes pitting and roughening of surfaces, but can also cause sharp scratches (Molleson et al., 1993; Hillson, 1996). Sliding wear occurs when a surface is pushed against another surface and moved sideways, with reoccurrence this type of wear may cause cracks in the enamel. Erosion is caused by particles moving in a fluid. Scratches are defined as an undeviating line and its length to breadth ratio are generally 2:1. Pits are easily identified and are measured in terms of size and shape (Teaford and Walker, 1984). Pit size and shape are directly related to the force applied as well as the size and shape of the particle. The greater the vertical force the greater the pit size, therefore, a smaller chance of scratches (Molleson et al., 1993). In the phase II wear facet, the expected pattern is that scratches are short, few, and randomly oriented; if there is a major deviation from this pattern it is likely that postmortem processes have affected the tooth (Teaford, 1988a).

There are various processes that can affect microwear features during an individual's life. As an individual ages, feature density tends to increase; however, the proportion of feature type does not change, because microwear formation is a plastic event (Molleson et al., 1993). Food texture affects microwear features. Generally, grit produces pits and scratches of varying degrees and number depending on the size of the grit; harder food equals wider pits, and large particles produce wider scratches (Organ et al., 2005; Mahoney, 2006a).

General trends in microwear reveal dietary behavior. Teaford (1986) and Teaford and Runestad (1992) determined that non-human primate soft fruit eaters had a higher percentage of scratches on teeth and hard objected eaters had a higher percentage of pits. Pits and scratches differ between living groups based on dietary differences. Diets with few abrasives tend to have less microwear features in general than those with firm and abrasive foods (Teaford, 1991; Teaford and Runestad, 1992, Teaford and Lytle, 1996). Phytolith rich soft plant foods leave a higher degree of scratches than pits (Grine, 1987; Schmidt, 2001; Teaford, 1988ab; Ungar and Spencer, 1999; Ungar and Teaford, 1996). Cultural behavior can also affect human microwear. Abrasive grit introduced to diet and created by stone tools tends to increase scratch frequency (Teaford and Lytle, 1996).

In this thesis, pits are features that have a length to width ratio less than 4 to 1. Pits are formed by intrusive elements such as food or grit creating fractures during the power stroke, in this case, on the occlusal surface on wear facet x or 10n (Maas, 1994). Pits can be caused by food itself or by grit introduced into food by processing or environment, such as sand or stone (Harmon and Rose, 1988; Ungar, 1995). Groups where pitting is the dominate microwear feature are non-human primates with hard diets (Teaford, 1986; Teaford and Runestad, 1992) and some pre-agricultural human groups (Bullington, 1991, Pastor, 1993, Organ et al., 2005; Mahoney, 2006a). Scratches are formed during phase I and II of the power stroke similarly to pits (Schmidt, 2010). Scratches dominate in soft diets. Trends with scratches are linked to differences in scratch width; generally wider scratches are common in pre-agricultural groups (Teaford, 1991; Schmidt, 1998; Organ et al., 2005).

Scanning Electron Microscope. The vast majority of dental microwear studies use a Scanning Electron Microscope (SEM) to observe microwear features (Ungar et al., 2008). In many cases, it is not possible to observe original dentition under an SEM because the teeth must be covered with a conductive material, effectively damaging the teeth. For this reason, casts are made with polyvinysiloxane impression material and epoxy resin, before coating in conductive material – most commonly gold palladium – to reduced static charges that affect image quality. The coating also protects specimens from damaging heat when observed with the SEM (Bozzola and Russell, 1999).

An SEM is used to examine 3D features in specimens up to 7.6-12.7 cm (Bozzola and Russell, 1999). An SEM is often divided into three parts: electron optical system, specimen stage, and a secondary electron detector. The electron optical system focuses and directs the electron beam, the specimen stage is where the sample is inserted, and the secondary electron detector perceives electrons and produces an image. A tungsten filament is used in most SEM's to produce and control the emission of electrons. For microwear analysis, it is common for the SEM to be set to secondary electron mode, where a detector reads the electrons shed by the specimen after the beam scans it. Secondary electrons are negatively charged and highly attracted to the positively charged detector (Bozzola and Russell, 1999).

Microwear 4.02 (Ungar, 2002). *Microwear 4.02* software, developed by Peter Ungar (2002), has revolutionized what was once a tedious part of microwear studies: quanifying and identifying features. Microwear features were once counted by hand creating an environment with potentially high interobserver error. *Microwear 4.02* has the ability to enhance the SEM micrograph and calculate summary statistics all at once (Ungar, 1995). This programs calculates major axis length, minor axis length, preferred orientation, major/minor axis ratios, vector length, length, width, and tally of pits, and length, breadth, orientation, vector length, and tally of striations (Ungar and Teaford, 2002)

Microwear 4.02 requires some subjectivity to identify each feature using a computer mouse. A feature is identified by using the mouse to point out the long and short axes. Pits are determined from scratches by adhering to a length to breadth ratio of 4:1 that is automatically set in the program. Grine et al. (2002) carried out a study to determine inter- and intra-observer error for the program. They determined that *Microwear 4.02* had an intraoberserver error rate of 7% and interobserver rate of 9%, though no score significantly differed. *Microwear 4.02* reduces error rates from other methods, and until a completely automated system is created, subjectivity will part of the process (Grine et al., 2002).

Studies of Microwear in Human Groups. Human microwear studies investigate multiple topics: comparing microwear between groups (Molleson and Jones, 1991; Organ et al., 2005; Mahoney, 2006a; El-Zaatari, 2008; Ma and Teaford, 2010;), dietary reconstruction (Organ et al., 2005; Domonkosova et al, 2010; Gamza and Irish, 2010; Ma and Teaford, 2010) experimental effects of food on modern human teeth (Teaford and Lyle, 1996), and observance of inter-facet and intra-tooth microwear variation (Mahoney, 2006b). Ma and Teaford (2010) observed microwear within the same sample time period, across different social economic groups in historic Balitmore. Molleson et al. (1993) used dental microwear analysis to determine if there was a difference in features between cooked and uncooked food, and Domonkosova et al. (2010) and used microwear analysis to aid in dietary reconstruction of individuals interred at the Gan Cemetery in Slovakia and Gamza and Irish (2010) reconstructed the diet of an Egyptian sample from Heirakonpolis. Gamza (2010) determined that there is no significant difference between adult and sub-adult microwear formation, concluding that it is possible to include them along with adult teeth in microwear studies

Microwear Considerations. There are several caveats that must be considered when conducting microwear analysis; a standardized method is still being developed. Common practice is to observe the phase II wear facets of molars, however, there is cross-study variation in which molar and phase II wear facet is examined. Magnification is variable as well; authors magnify samples anywhere from 200x to 1500x, producing different fields of vision. While the quantification of features has been focused to using a standard program, there are no specific criteria for using this program. For example, if the line or pit extends past the edge of the micrograph is it still included in analysis? Factors like this one must be considered if studies are to be comparable.

Using the SEM has drawbacks: First, there is a loss of information from the 3D tooth surface and the 2D image produced. Second, there is high measurement error, but programs like *Microwear 4.02* have helped to mitigate the impact of measurement error on results (Ungar et al., 2008). To address the 3D issue, Ungar and colleagues (2008) have developed a new method termed dental microwear texture analysis. This method addresses all of the draw backs of SEM analysis, by producing measurements in 3D using a white-light confocal microscope and scale-sensitive fractal analysis to identify changes in texture (Ungar et al., 2008).

Postmortem wear should be carefully identified during microwear analysis. A number of studies have investigated the effects of post-mortem wear on microwear features (Teaford, 1988a; King et al., 1999). Both studies conclude that post mortem wear does not create new features; rather it masks features that are already present. Post-mortem wear is identifiable in dentition, therefore, the main issue is that dentition with evidence of post-mortem wear must be removed from the study, in some cases substantially reducing sample size (Teaford, 2007b).

Microwear is only representative of diet up to seven days or less, known as “the last supper” (Grine, 1986). The “last supper” phenomenon must be carefully considered in human dietary reconstruction as human diets are highly variable. A number of experimental studies have been completed to investigate the rate of microwear turnover in humans and animals (Covert and Kay, 1981; Teaford and Oyen, 1989; Teaford and Lytle, 1996). Teaford and Lytle (1996) observed the effect of different amounts of maize on modern human dentition, and tracked changes from week to week. They concluded that human microwear features can turnover in 8-18 days (Teaford and Lytle 1996).

When interpreting microwear features in humans there is no reliable way to draw conclusions without observing pits, scratches, and prisms within the archaeological context of the prehistoric groups being studied. For example, what type of food evidence has been discovered at the site? And what does stable isotope analysis say about diet? (Teaford, 2007a). Even if these questions are answered it may only be possible to comment on the texture of food, not specifics about the types of foods eaten. Food processing techniques must also be taken into consideration as differences in these techniques can introduce particles into food, influencing microwear.

Despite the draw backs, dental microwear analysis in human dietary reconstruction is a highly informative field of study. Dental microwear analysis (DMA) provides the opportunity to study the effect of what an individual has directly interacted with and ingested. DMA is also a non-destructive method of study that can be used in lieu of other methods when destruction of the sample is not allowed. The study of microwear continues to evolve and develop, creating an understanding of diet in humankinds past.

Dental Morphology using the Arizona State University Dental Anthropology System

Researchers that study dental morphology are attempting to identify significant variation in tooth form, such as cusps and fissures. These features vary when affected by microevolutionary forces such as gene flow and natural selection (Scott and Turner, 1997). The Arizona State University Dental Anthropology System (ASUDAS) is the standard method used to identify non-metric dental traits. There are several reasons for this: 1) the traits are evolutionarily stable, 2) most of the traits are observable even through a fair amount of dental wear, 3) the traits are easy to locate and identify, 4) they are independent of one another, 5) they are not affected by sexual dimorphism, 6) they are independent of tooth size, 7) there is a genetic influence on the traits, and 8) there is a vast amount of comparable data available (Turner et al., 1991; Scott and Turner, 1997; Irish, 2005). The ASUDAS consists of 24 rank-scale reference plaques and detailed descriptions of each trait and its various forms (Appendix C).

Before the ASUDAS was developed, non-metric dental traits were used by a variety of researchers to document population differences or general differences in trait expression (Hrdlička, 1920; Hellman, 1928; Dalhberg, 1945, 1963; Pedersen, 1949; Pedersen and Scott, 1951; Kraus, 1951, Moorrees, 1957). Over time, researchers developed dental complexes for multiple world populations, investigated population origins, and biological distance studies between and within groups (Berry, 1976; Turner, 1984; Greene, 1982; Sofaer et al., 1986). After the development of the ASUDAS, non-metric studies expanded to include a wide variety of topics as well as contributing to a massive comparable data set. These topics include, investigation of origins, biological affinity, establishing and clarifying dental complexes, biological distance, hominid morphology, clarifying non-metric traits within the ASUDAS, and observing within and between group differences (Irish, 1997, 1998a, 1998b, 2000, 2006; Guatelli-Steinberg et al., 2001; Jackes et al., 2001; Bailey, 2002, 2006a, 2006b; Irish and Guatelli-Steinberg, 2003; Higa et al., 2003; Ullinger et al., 2005; Guatelli-Steinberg and Irish, 2005; Hanihara, 2008; Leblanc et al., 2008; Vargiu et al., 2009; Schillaci et al., 2009; Irish and Friedman, 2010).

ASUDAS traits do not follow simple inheritance patterns (Scott and Turner, 1997). The underlying assumption of most studies using the ASUDAS is that phenetic similarity or difference can be used to approximate genetic similarity or difference (Scott and Turner, 1997; Irish, 1997, 1998ab, 2010; Ullinger et al., 2005). To validate the previous assumption, investigations of dental morphology and genetic transmission have been helpful. Studies that investigate morphology and genetics look at different facets: the transmission of individual traits, the genetics of dental development, comparing genetic evidence with morphological evidence, and twin studies (Kraus, 1951; Goose and Lee, 1971; Garn, 1977; Biggerstaff, 1979; Harris and Bailit, 1980; Nakata, 1985; Boraas et al., 1988; Nichol, 1989; Townsend and Martin, 1992; Jernvall and Jung, 2000;

Townsend et al., 2009; Ricaut et al., 2010). All conclude that dental morphology is at least partly genetically controlled. The question persists: how are these traits expressed and transmitted? Currently, the effect of genes and environment in regards to dental morphology has not be differentiated; however, when comparing dental morphological and genetic differences there is a fair amount of concordance when observing broad relationships, not close familial relationships (Cavalli-Sforza et al., 1994; Scott and Turner, 1997; Ricaut et al., 2010).

The formulators of the Arizona State University Dental Anthropology System have addressed many of the drawbacks inherent in morphological studies by carefully choosing traits and developing visual and written aids to identify these traits. Nichol and Turner (1986) tested inter- and intra-observer error in the recording of non-metric traits using and determined that plaques and written descriptions decrease inter- and intra-observer error. Traits included in the ASUDAS were known to be independent, not effected by sexual dimorphism, were genetically controlled, and were easy to identify (Turner et al., 1991; Scott and Turner, 1997). If the dentition is influenced by asymmetry, common practice is to score an individual for all traits and including only the tooth with the highest expression of a given trait in statistical analysis (Turner et al., 1991; Scott and Turner, 1997). Because traits chosen are not affected by sexual dimorphism standard methods dictate that males and female dentition is pooled (Scott and Turner, 1997).

A statistic commonly used in studies observing non-metric dental traits to estimate biological affinity is C.A.B. Smith's mean measure of divergence statistic

(MMD) (Equation 1) (Berry and Berry, 1967; Sjøvold, 1973, 1977; Berry, 1976; Larsen, 1997; Irish and Guatelli-Steinberg, 2003). The MMD statistic is a measure of distance; therefore high values indicate dissimilarity and low values similarity. This statistic does not function well with ordinal level data; therefore data were dichotomized using standard breakpoints (Scott and Turner, 1997).The Freeman and Tukey (1950) (Equation 1) transformation, recommended by Green and Suckey (1976) used in association with the MMD, adjusts variance in small sample sizes (Irish and Guatelli-Steinberg, 2003; Irish, 2010). The MMD was used in conjunction with the Freeman and Tukey angular transformation to adjust for small sample sizes (less than or equal to 10) and for high and low frequency traits (Sjøvold, 1977; Green and Suchey, 1976). The MMD has come under some criticism, however, Irish (2010) demonstrated that as long as the statistic is used correctly with the appropriate transformation it can be used effectively.

$$MMD = \frac{\sum_{i=1}^{r}(\theta_{1i} - \theta_{2i})^2 - (1/(n_{1i} + {}^{1}/_{2}) + 1/(n_{2i} + {}^{1}/_{2})}{r} \qquad (1)$$

r= number of uncorrelated traits
θ= angular transformation
n= number of individuals examined for trait "i"

Isolation-by-Distance Stepping Stone Model. Phenetic distance (MMD values) and geographic distance (km) are compared in this these to determine if a correlation between the two exists and is then analyzed using the isolation-by-distance model (Irish, 2010). The isolation-by-distance stepping stone model assumes that between two geographically dispersed populations there are an infinite number of small populations; gene flow occurs between adjacent groups at a higher rate than non adjacent groups. This model assumes an infinitely large population with limited gene flow. If the model fit the data, groups that are phenetically similar will be closer geographically and groups phenetically dissimilar will be farther apart unless another event has influenced the groups (Kimura and Weiss, 1964; Konigsberg, 1990; Irish, 2010; Schillaci et al., 2009). The isolation-by-distance stepping stone model is used in this thesis because potential migration routes are not the focus here; instead, a general relationship between genes and geography, and the stepping stone model is the most parsimonious way to investigate that relationship.

CHAPTER 4

MATERIALS AND METHODS

Feteira II

As previously mentioned, Feteira II samples from layers A and B have been radio-carbon dated to the Middle to Late Neolithic period in the Estremadura region (3,600-2,900 B.C.E.). The dental remains from this site are mostly isolated and consist of approximately 1500 deciduous and permanent teeth and bone fragments in which 88.79% were fragmented and not in association with the remains of a single individual. The MNI for this site is approximately 42 adults (over 17 years of age) and 26 sub-adults (under 17 years of age, most 7 years old or less) for a total of 68 individuals (Waterman, 2006). Human dentition from layers A, B, and C have been pooled in this study to increase sample size.

Bolores

The human remains from Bolores were dated to the Late Neolithic to Early Bronze Age periods in the Estremadura (2800–1800 B.C.E). The dental remains from Bolores are primarily isolated or limited to a few maxillary and mandibular fragments. The MNI was calculated for a total of 22 individuals: eight children from 0-10 years old, three adolescents from 10-21 years old, and 11 adults (Lillios et al., 2010: 29).

Microwear Methods

All second left mandibular molars, without post-mortem damage or casting defects on the wear facet x or 10n, were observed for microwear in adults. In juveniles, deciduous second premolars were used. Because these samples consist of mostly isolated teeth, rules of usage were established to prevent observing one individual multiple times. Models and casts were produced in the University of Alaska, Department of Anthropology, Chemical Bioarchaeology and Biological Anthropology Laboratories operated by Dr. Kara Hoover. Molds were taken of all molars in suitable condition using Coltène® President Jet Plus Light Body, a polyvinylsiloxane impression material. Suitable condition was defined as teeth without any obvious post-mortem wear or teeth without enamel cracks or damage. The polyvinylsiloxane impression material has been used by many researchers because it is accurate enough for SEM analysis and is safe for fragile teeth (Benyon, 1987; Schmidt, 1999; Galbany et al., 2004; Fiorenza et al., 2009). Light body polyvinylsiloxane impression materials get very close to the surface of the teeth and consist of a catalyst and base that produce shearing forces when mixed, causing the substance to flow along the surface of the tooth; this force allows the material to pour into hard to access areas (Benyon, 1987). This silicone based material has low viscosity that leads to a more accurate mold (Fiorenza et al., 2009). The dentition was examined prior to the molding process; any tooth with flaking, or cracked enamel was not chosen for study to preserve the dentition from damage (Fiorenza et al., 2009). Prior to using the polyvinylsiloxane material all teeth were cleaned using a cotton swab to remove any surface contamination such as dirt or dust (Ungar and Spencer, 1999; Galbany et al., 2004). The samples analyzed were not treated with any preservative and only had been cleaned using dry techniques (Lillios and Waterman, personal communication, 2011). The impression material was applied to the teeth using a dispenser gun. Molds were allowed to cure on the teeth for up to five minutes until completely set. They were then carefully removed and place in individual open plastic bags to degass for 24 hours. The degassing process prevents bubbles from occurring in the mold (Schmidt, 1999).

Casts were made of the teeth using Specifix-20, a cold cure Epoxy Resin produced by Streurs. Epoxy Resins, such as Specifix-20, can produce accurate high quality replicas, are durable, and cure at room temperature (Galbany et al., 2004; Fiorenza et al., 2009). Molds were cleaned with isoproprol alcohol and a cotton swab and rinsed with ultra pure water. They were allowed to air dry for 24 hours. The molds were then set in modeling clay in 50mL tubes and filled with cotton balls (Waters and Savage, 1971; Rose, 1983; Fiorenza et al., 2009). A disposable pipette was used to distribute the epoxy mixture, limiting the amount of air bubbles in the molds (Schmidt, 1999). Once filled, the molds were spun down for 1 min at 2300 rpm, lids on, and were allowed to dry, lids off, in the fume hood for 48 hours. A centrifuge was used to remove bubbles and to force the resin into the mold, removing any space left between the mold and the epoxy (Schmidt, 1999). Once fully cured the molds were observed under a compound microscope at 50x to determine whether the cast was of the required quality for use under the SEM. The cast was removed from analysis if there were defects.

The standard method for use in the scanning electron microscope is to sputter coat the object with approximate 216 angstroms of gold palladium. Casts were made to preserve teeth from the gold coating process. The cured mold was allowed to degas for 48 hours and cleaned with ultra pure water before it was sputter coated to prevent casting artifacts and to remove any item on the surface of the mold. Once the mold was dried it was mounted to an aluminum stub and placed inside the chamber on the Ladd sputter coater. This process can cause the specimen to experience damaging levels of heat; therefore the dental casts were coated for thirty seconds, allowed to rest in the chamber for two minutes and coated for an addition sixty seconds (Severin, personal communication, 2012).

Micrographs were taken, using the SEM, of phase II wear facets on the protoconid. Micrographs of the x and 10n wear facet were taken and the most accurate picture was chosen to include in analysis. The phase II x facet is located on the distal portion of the protoconid of the mandibular molar and the distal portion protocone of the maxillary molar. The phase II 10n facet is located on the mesial portion of the protoconid of the mandibular molar and the mesial portion of the protocone in the maxillary molar (Kay, 1977; Gordon, 1984). These facets are both phase II facets, occupy the same cusp, and experience the same forces, thus they are comparable. Phase II wear facets of the protoconid are located by focusing on a position halfway between the tip of the cusp and the central groove (Ungar, 1996). In the case that the cusps were worn flat, micrographs were taken from the buccal half of the central groove on the protoconid for the x and 10n facet.

The International Scientific Instruments (ISI-SR-50) scanning electron microscope (SEM) at the Advance Instrumentation Laboratory at the University of Alaska Fairbanks was used to obtain images. The SEM was set to secondary emission mode with a magnification of 500x approximately $0.02m^2$, a working distance of 25, and Kv of 25 (Greene, 2006). Images of the phase II wear facets were transferred to a computer from the SEM and analyzed by *Microwear 4.02*. Micrographs contrast and sharpness were adjusted so all the features could be easily identified. Rules were established for measuring each feature: 1) any line or feature that was cut off by the micrograph was measured, 2) width was measured only where the red line fell directly in the groove, and 3) the size of the micrograph was kept constant.

Summary statistics generated by *Microwear 4.02* were analyzed in PASW® 18.0 using an independent samples t-test. The t-test statistic is used to compare one continuous variable in two different samples and is a very robust statistic (Norušis, 2010). In this case, multiple t-test statistics were computed to compare the following variables: percentage of pits, scratch width in microns, scratch breadth in microns, pit width in microns, percentage of scratch occurrence, percentage of pit occurrence, scratch tally and pit tally.

Levene's test was used in conjunction with the independent samples t-test to determine whether the Feteira II and Bolores originate from populations with equal variance. If there is not equal variance, then individual sample variances are used (Norušis, 2010). If there is equal variance, pooled estimates of the variance will be used (Norušis, 2010). The independent samples t-test is used because Bolores and Feteira II are assumed to be unrelated populations whose distribution is normal. Adult and sub-adult dentitions were pooled as there is no significant difference between microwear formation in adult and sub-adult dentition (Gamza, 2010).

Arizona State University Dental Anthropology System Materials

Fifteen Comparative Samples. Fifteen comparative samples are used to help characterize the morphology of groups at Feteira II and Bolores. These samples morphology data were generously provided by Dr. Joel Irish. While samples from northern and central Europe would be ideal to specifically address questions of Bell Beaker migrants, data constraints limited comparative groups to the northwest Africa, Egypt, and Nubia and elsewhere in the Mediterranean area. Samples include groups from Ancient Palestine, Italy, Greece, and Turkey, affinities to groups in these regions could reveal possible gene flow from the Mesolithic/Neolithic transition, described in Chapter 2. Northwest African samples include individuals from Tunisia, Algeria, Morocco, and Libya. Northwest African samples are compared to investigate whether African cultural items found in Portugal during the Late Neolithic and Copper Age were accompanied by significant gene flow. Egyptian (Abydos, Kharga, Tarkan, Hierakonpolis, and Saqqara) and Nubian (Kerma) samples are used because their used dates correspond with Feteira II or Bolores, or as is the case with the Kharga sample is a good control for the isolation-by-distance model because its use date is after that of both Feteira II and Bolores and is geographically distant. For a complete description of each sample refer to Appendix D.

Table 2. Dental morphology samples.

Samples	Dates	Geographical location	n	Source
Abydos (ABY)	3000-2686 B.C.E.	Egypt	54	Irish, 2006; Irish and Friedman, 2010
Bedouin (BED)	1800-1900 AD	Morocco, Tunisia, Libya	49	Guatelli-Steinberg et al., 2001; Irish, 2000
Bolores (BOL)	2800-1800 B.C.E.	Portugal	22	Current Study
Capsian (CAP)	6500-3000 B.C.E.	Tunisia, Algeria	22	Irish, 2000
Feteira II (FET)	3600-2900 B.C.E.	Portugal	68	Current Study
Greek (GRK)	475-300 B.C.E., historic period	Greece	77	Irish, personal communication, 2012
Hierakonpolis (HRK)	3500-3200 B.C.E.	Egypt	247	Irish, 2006; Irish and Friedman, 2010
Italy (ITY)	30 B.C.E-AD 395/modern period	Italy	90	Irish, personal communication, 2012
Kabyle/Berber (KAB)	1800-1900 AD	Algeria	32	Guatelli-Steinberg et al., 2001; Irish, 2000
Kerma (KER)	1750-1500 B.C.E.	Nubia	63	Irish, 2005; Irish and Friedman, 2010
Lachish- Bronze (LCB)	3300-1098 B.C.E.	Palestine	34	Dicke-Toupin, 2012
Saqqara (SAQ)	20613-2494 B.C.E.	Egypt	41	Irish,2006; Irish and Friedman, 2010
Lachish- Iron (LCI)	1200-520 B.C.E.	Palestine	365	Dicke-Toupin, 2012
Shawia/Berber (SHA)	1800's AD	Algeria	26	Guatelli-Steinberg et al., 2001, Irish, 2000
Tarkhan (TAR)	3000-2890 B.C.E.	Egypt	51	Irish, 2006; Irish and Friedman, 2010
Thebes (THE)	2055-1773 B.C.E.	Egypt	54	Irish, 2006; Irish and Friedman, 2010
Turkey (TRK)	Classic period ~300 B.C.E.	Turkey	40	Irish, personal communication, 2012

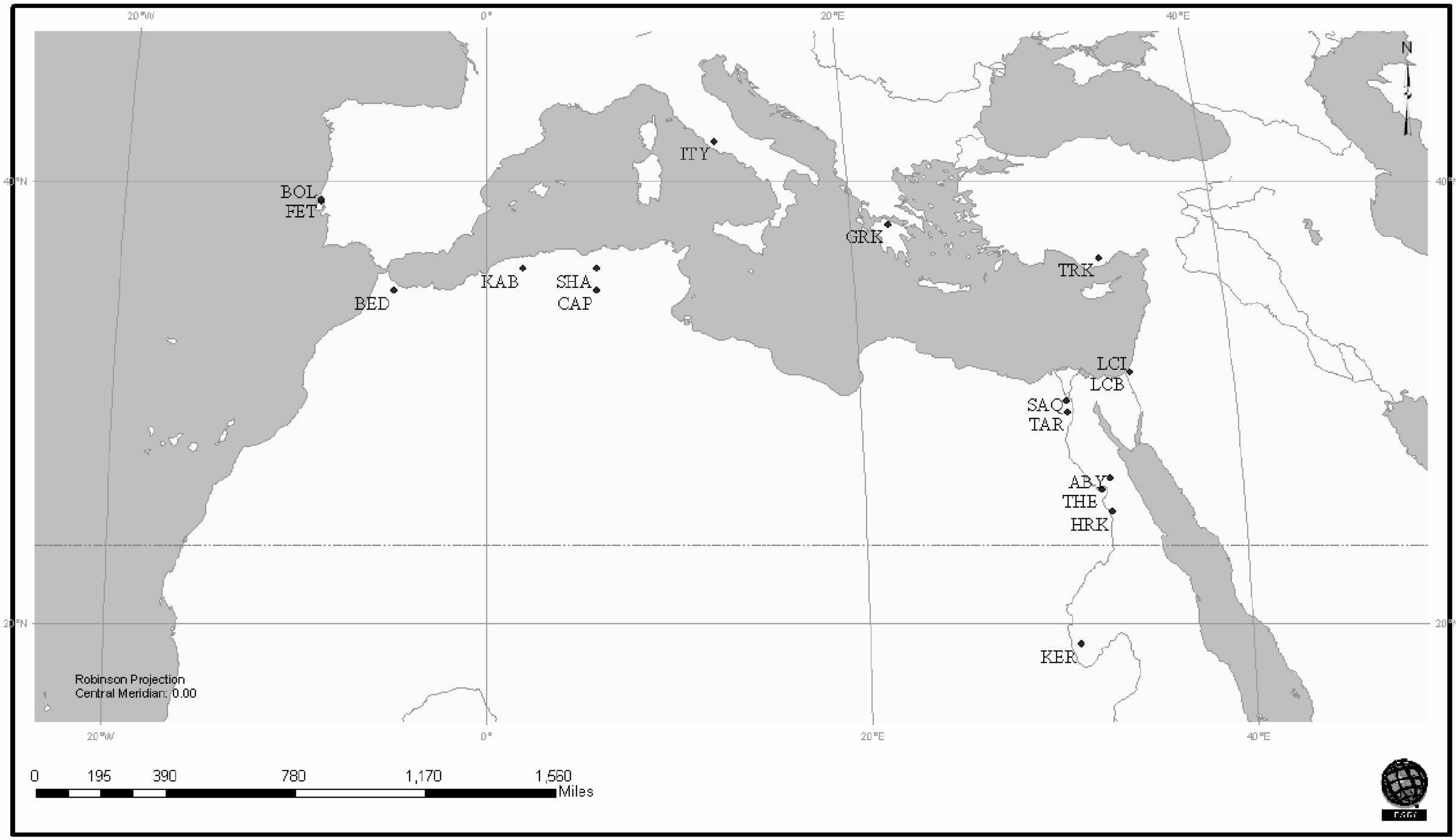


Figure 5. Dental morphology samples.

Arizona State University Dental Anthropology System Methods

Thirty-six morphological dental and osseous traits were recorded in individual permanent teeth, as well as any mandibular or maxillary fragments present, using 24 reference plaques. Because of the fragmentary nature of the Bolores and Feteira II samples, composite individuals were created to limit the probability of counting an individual multiple times for a given trait (Irish, personal communication, 2010). Once these individuals were created the antimere with the highest expression was included in statistical analysis; if only one tooth was available for scoring, it was automatically included (Turner et al., 1991). Males and females were pooled as is standard in ASUDAS protocol (Irish, 1997).

All data were entered into a PASW® (Predictive Analytic Software) 18.0 database and MMD statistic was used to determine similarity between Feteira II and Bolores and 15 comparative samples. The Freeman and Tukey (1950) transformation is used in conjunction with the MMD statistic to adjust for variance in small samples (Green and Suchey, 1976; Irish, 2010).

Mean measure of divergence values and geographic distances (km) were compared using the Pearson’s R correlation coefficient using PSAW® 18.0. Specifically, to determine the relationship between phenetic distance and geographic distance, correlations were calculated between the mean measure of divergence values and actual geographic distance (km) between samples. The geographic location of each sample was plotted in decimal degrees on a Robinson Projection world map. Straight line distances were calculated between samples using the measure tool in ArcGIS® 9.3.1. (ESRI, 2011)

Correlations were examined using Wright's (1938, 1940, 1943) isolation-by-distance stepping stone model to compare MMD values and geographic distance to determine if a correlation between the two exists (Kimura and Weiss, 1964, Konigsberg, 1990, Irish, 2010). Ordinarily a Mantel Test would be used to determine the correlation between genes and geography; however, in this case, no MMD distance matrix was available. Two qualitative methods were used to illustrate the correlation between phenetic distance and geographic distance: scatterplots and a purely heuristic star map (Turner, 1995; Guatelli-Steinberg et al., 2001; Irish, personal communication, 2012). The star maps were constructed by plotting the ratio of phenetic to geographic distance in kilometers in Euclidean space. The maps illustrate the relationship between phenetic and geographic distance but do not visualize absolute relationships because the line, which represents phenetic distance, is dependent on geographic distance, which is relative to map scale and projection.

CHAPTER 5

RESULTS

Feteira II versus Bolores Microwear

Results from the independent samples t-test investigating microwear variables between Feteira II and Bolores reveal no significant difference between the groups (Table 3). The table below provides sample size for each site, the range of the number of microwear features in each group, and the mean number of features. When comparing the individuals interred at Feteira II and Bolores adults and sub-adults are pooled. Gamza (2010) determined that sub-adults do not have different microwear features due to differences in enamel microstructure, therefore, sub-adults were included to increase sample size. Sample size is indicated by tooth number studied. Seventeen individual teeth in Feteira II and 5 individual teeth in Bolores were observed for microwear features. Sample size was reduced due to the removal teeth because of post mortem wear or other damage.

Table 3. Summary results for Bolores and Feteira II.

Sites	n	Range of microwear features (Adult)	Mean no. features
Feteira II	17	22-138	74.71
Bolores	5	71-134	81.60

Feature Tally. An independent samples t-test was used to compare the total number of microwear features, both pits and scratches, between Feteira II and Bolores. The mean number of features for second mandibular molars found at Feteira II is 74.71 and for Bolores are 81.60. The Levene test is significant, thus equal variance cannot be assumed (0.015). The independent samples t-test indicates there is no significant difference between Feteira II and Bolores for number of microwear features (Table 4).

Table 4. Results from the independent samples t-test for feature tally.

Site	n	Mean	Standard Deviation	P-Value
Feteira II	17	74.71	29.72	0.666
Bolores	5	81.60	30.05	

Scratch Length. An independent samples t-test was used to compare scratch length between Feteira II and Bolores individuals. The mean scratch length in microns is 34.64 for Feteira II and 33.10 for Bolores. Equal variance can be assumed (0.504) using Levene's test. There is no significant difference between Feteira II and Bolores for scratch length (0.593) (Table 5).

Table 5. Results from the independent samples t-test for scratch length.

Site	N	Mean	Standard Deviation	P-Value
Feteira II	17	34.64 μ	4.92 μ	0.593
Bolores	5	33.10 μ	7.61 μ	

Scratch Breadth. An independent samples t-test was used to compare the scratch breadth between Feteira II and Bolores individuals. The mean scratch breadth in microns is 2.49 for Feteira II and 2.75 for Bolores. Variance cannot be assumed equal using Levene's test (0.057) and there is no significant difference between Feteira II and Bolores (0.597) (Table 6).

Table 6. Results from the independent samples t-test for scratch breadth.

Site	n	Mean	Standard Deviation	P-Value
Feteira II	17	2.49 μ	0.63 μ	0.597
Bolores	5	2.75 μ	0.98 μ	

Percentage of Scratches. An independent samples t-test was used to compare the percentage of scratches out of the total number of microwear features between Feteira II and Bolores individuals. The mean percentage of scratches for Feteira II is 66.94% and for Bolores is 63.00%. Using Levene's test it is assumed that the two groups have equal variance (0.864). There is no significant difference between Feteira II and Bolores for percentage of scratches (0.538) (Table 7).

Table 7. Results from the independent samples t-test for percentage of scratches.

Site	n	Mean	Standard Deviation	P-Value
Feteira II	17	66.94%	11.99%	0.538
Bolores	5	63.00%	13.75%	

Pit Width. An independent samples t-test was used to compare the pit width between Feteira II and Bolores. The mean pit width for Feteira II is 4.85 microns and for Bolores is 4.83 microns. Levene's test supports equal variance between samples (0.540), and there is no significant difference between Feteira II and Bolores for pit width in microns (0.982) (Table 8).

Table 8. Results from the independent samples t-test for pit width.

Site	n	Mean	Standard Deviation	P-Value
Feteira II	17	4.85 μ	0.95 μ	0.982
Bolores	5	4.84 μ	1.07 μ	

Percentage of Pits. An independent samples t-test was used to compare the percentage of pits out of the total number of microwear features between Feteira II and Bolores individuals. The mean percentage of pits for Feteira II individuals is 33.06% and for Bolores is 37.00%. The Levene test is not significant, thus equal variance can be assumed (0.864). There is no significant difference between Feteira II and Bolores for percentage of pits (0.538) (Table 9).

Table 9. Results from the independent samples t-test for percentage of pits.

Site	n	Mean	Standard Devation	P-Value
Feteira II	17	33.06%	11.99%	0.538
Bolores	5	37.00%	13.75%	

Biological Affinity

In order to determine biological affinity between Feteira II and Bolores individuals and to compare the aforementioned groups to other world groups, the mean measure of divergence statistic was calculated (Irish, 2000, 2005, 2006). Table 10 shows the percentage of individual teeth that present a trait and the total number of teeth scored. Inter- and intra- observer errors were calculated using a paired samples t-test between all three individuals that scored samples presented in this research and no significant difference was found. There are a few samples that are affected by small sample size, such as Bolores, Lachish Bronze Age, and Capsian. Results from these groups will be interpreted with caution as they may not be representative of the populations from which they come (Irish, 2005, 2006)

Table 10. Dental trait frequencies and percentages for dental morphology samples.

		BOL	FET	ABP	BED	CAP	GRK	HRK	ITY	KAB	KER	LCI	LCB	SAQ	SHA	TAR	THE	TRK
Traits																		
Winging UI 1	%	0	0	2.5	5.4	0	1.5	5.4	3.9	0	5.4	0	0	2.8	0	6.8	5.6	0
(+= ASU 1)	n	0	0	40	37	5	68	167	76	29	56	21	7	36	26	44	54	36
Labial Curvature UI1	%	0	0	0	8.3	0	0	8.3	0	12.5	7.7	0	14.3	0	14.3	6.7	4.8	0
(+=ASU 2-4)	n	11	31	21	24	4	5	109	29	8	13	15	7	11	7	30	21	10
Palatine Torus	%	0	0	0	2.4	0	4.3	0	10.4	3.4	1.8	0	0	0	0	0	0	0
(+= ASU 2-3)	n	0	0	39	41	10	70	125	77	29	55	355	32	39	25	44	51	35
Shoveling UI 1	%	0	5.1	5.9	8	0	0	17.6	26.9	14.3	22.2	6.3	0	0	0	7.1	15.8	0
(+= ASU 2-6)	n	10	39	17	25	5	5	102	26	7	9	16	7	7	7	28	19	10
Double Shoveling UI 1	%	0	0	0	12.5	0	0	4.5	0	12.5	0	0	0	0	25	0	0	0
(+= ASU 2-6)	n	11	43	17	24	5	5	110	27	8	7	16	7	8	8	26	18	10
Interruption Groove UI2	%	61.5	16.7	27.8	37.5	60	35	25.2	13.3	21.4	9.1	3.1	0	33.3	46.2	8.8	20.8	15.4
(+= ASU +)	n	13	42	18	24	5	20	115	30	14	11	32	7	9	13	34	24	13
Teburculum Dentale UI2	%	46.2	22	25	43.5	60	5.3	36.7	36.7	50	8.3	29.4	30	66.7	25	28.1	30	15.4
(+= ASU 2-6)	n	13	41	16	23	5	19	109	30	12	12	34	10	6	12	32	20	13
Bushman Canine UC	%	0	0	0	0	22.2	8.7	5	2.6	0	16.7	0	0	0	0	5.4	3	0
(+= ASU 1-3)	n	16	41	17	29	9	23	120	39	16	18	77	14	10	4	37	33	19
Distal Accessory Ridge UC	%	54.5	84.6	20	12	42.7	8.3	12.6	19.2	27.3	18.2	8.3	0	0	22.2	3.8	10.5	6.3
(+= ASU 2-5)	n	11	39	15	25	7	12	103	26	11	11	36	4	6	9	26	19	16
Hypocone UM2	%	77.8	73.7	66.7	58.8	100	50	86.6	59.7	63.6	91.7	77	85.7	95.7	68.4	75	85.7	60
(+= ASU 3-5)	n	9	38	33	34	10	54	157	72	22	48	217	21	23	19	40	42	25
Cusp 5 UM1	%	44.4	31.4	10	8.8	30	5.7	15.5	17.5	11.8	24.1	29.5	24	0	10	0	14.3	4.5
(+= ASU 3-5)	n	9	35	20	34	10	53	97	63	17	29	251	25	9	20	23	28	22
Carabelli's Trait UM1	%	45.5	59.5	90.5	54.5	100	8.5	80.8	61.3	57.9	51.6	71.3	89.5	1	55.6	67.9	90.3	85.7

Table 10. Continued.

(+= ASU 1-5)	n	11	37	21	33	6	48	104
Parastyle UM 3	%	0	0	0	0	0	0	0
(+= ASU 1-5)	n	9	36	28	20	9	33	142
Enamel Extension UM 1	%	10	8.6	11.8	5.6	0	16.7	19.5
(+= ASU 1-3)	n	10	35	34	36	13	54	164
Root Number UP 1	%	12.5	33.3	69.4	50	33.3	61.9	59.8
(+= ASU +)	n	8	30	49	32	12	63	164
Root Number UM 2	%	75	84.4	92.9	69	85.7	58.3	75.6
(+= ASU 3+)	n	4	32	28	29	7	36	119
Peg/Reduced Incisor UI 2	%	0	0	1.9	0	0	0	3.6
(+= ASU P or R)	n	13	44	52	27	10	73	197
Odontome P1-P2	%	11.1	10	2.5	0	0	0	1.3
(+= ASU +)	n	18	40	40	40	12	44	156
Congenital Absence UM 3	%	0	0	6.7	21.1	16.7	17.6	8.1
(+= ASU -)	n	8	42	45	38	12	68	184
Midline Diastima UI 1	%	0	0	5.4	8.8	0	3	2.8
(+= 0.05mm)	n	0	0	37	34	5	66	168
Lingual Cusp LP 2	%	66.7	69.2	65.4	64.3	84.6	60	81.4
(+= ASU 2-3)	n	3	26	26	28	13	10	129
Anterior Fovea LM 1	%	37.5	33.3	22.2	37.5	45.5	36.4	21.6
(+= ASU 2-4)	n	8	24	18	24	11	11	74
Mandibular Torus	%	0	0	0	2.9	0	0	0.5
(+= ASU 2-3)	n	0	0	53	35	19	34	178

62	19	31	164	19	16	18	28	31	21
0	0	5.4	1.6	0	0	7.7	2.6	0	0
41	22	37	128	9	15	13	38	37	13
5.8	0	4	5.5	0	0	4.8	0	4.8	25
69	23	50	255	8	18	21	45	42	24
5.9	52.2	80.4	56.8	54.5	89.7	52.2	75	85.3	69
59	23	51	199	11	29	23	32	34	29
76.9	68.4	90.2	85.9	100	82.6	72.2	72.2	81.3	62.1
39	19	41	64	5	23	18	18	32	29
9.6	6.2	1.6	4.9	0	6.1	0	4	0	5.7
83	16	63	61	10	33	13	50	54	35
2.7	0	0	0.5	0	0	0	0	5.1	0
74	22	41	218	21	12	23	43	39	30
23.5	3.4	16.7	16.1	15	20	23.1	4.1	19.6	21.9
81	29	60	310	20	35	26	49	51	32
4.9	12	3.3	4.8	0	0	0	4.2	1.9	0
82	25	60	21	2	33	23	48	53	37
34.9	69.2	86.4	71.4	100	66.7	92.3	77.8	70.3	82.4
43	13	22	28	3	12	13	18	37	17
51.4	60	43.8	20.8	100	14.3	29.4	0	42.9	40
35	10	16	24	1	7	17	2	14	10
0	0	0	3.8	0	0	4.2	0	0	0
73	19	60	78	8	37	24	49	52	30

Table 10. Continued.

Grove Pattern LM 2	%	9.1	0	15.2	46.9	41.2	43.5	37.1
(+= ASU Y)	n	11	39	46	32	17	23	175
Rocker Jaw	%	0	0	17	9.4	17.7	30.3	22.2
(+= ASU 6+)	n	0	0	47	32	17	33	144
Cusp Number LM 1	%	8.3	14.3	3.5	12.5	17.7	0	9.5
(+= ASU 6+)	n	12	35	29	32	17	19	137
Cusp Number LM 2	%	18.2	48.6	37.8	42.9	38.9	47.6	36.5
(+= ASU 5+)	n	11	35	37	28	18	21	137
Deflecting Wrinkle LM 1	%	12.5	4.6	21.7	15.6	20	17.6	20.5
(+= ASU 2-3)	n	8	22	23	32	10	17	112
C1-C2 Crest LM 1	%	0	0	0	3	0	5.9	3.9
(+= ASU+)	n	8	21	28	33	9	17	102
Protostylid LM1	%	0	0	0	0	0	0	1.4
(+= AUS 1-6)	n	10	27	30	33	15	19	139
Cusp 7 LM 1	%	10	0	5.1	5.9	16.7	5.6	6.2
(+= ASU 2-4)	n	10	33	39	34	18	18	177
Tomes Root LC	%	0	3.6	17.4	6.3	0	7.1	14.3
(+= ASU 2+)	n	9	28	46	32	15	28	175
Root Number LC	%	0	0	2	0	0	3.4	6.1
(+= ASU 2+)	n	8	32	49	26	12	29	179
Root Number LM 1	%	0	3.3	5.6	0	5.9	0	2.2
(+= ASU 3+)	n	7	30	36	33	17	22	136
Root Number LM 2	%	100	93.1	84.4	88.9	85.7	91.3	89.1
(+= ASU 2+)	n	9	29	32	27	14	23	128
Torso Angle LM 3	%	0	0	13.3	20	23.1	13	7.4
(+= ASU +)	n	0	0	45	25	13	23	148

26.2	27.8	41.3	34	40	22.7	36.8	30.6	25	5.9
61	18	46	50	5	22	19	36	48	17
12.5	10.5	5.3	0	0	24.3	8.3	16.3	22.6	13.8
72	19	57	81	7	37	24	43	53	29
2	31.3	0	3.9	0	0	9.5	5	2.8	0
51	16	28	51	2	10	21	20	36	19
35.6	33.3	41.2	37.7	37.5	25	31.6	50	26.3	41.2
45	18	34	69	8	12	19	28	38	17
12.5	6.7	11.1	0	0	0	5	12.5	13.3	6.7
48	15	27	14	2	8	20	16	30	15
6.4	0	0	0	0	0	0	0	0	0
47	14	27	18	2	5	20	16	26	13
0	0	0	1.5	0	0	0	0	0	0
51	16	26	67	5	14	21	20	41	17
5.4	5.9	17.1	6.1	0	0	4.8	3.7	6.8	0
56	17	35	33	2	20	21	27	44	19
10.5	5.3	25	3	0	6.7	10.5	13.6	11.1	0
57	19	52	33	2	30	19	44	36	25
3.3	20	1.9	0	0	6.1	0	4.4	0	0
60	10	52	69	9	33	16	45	35	22
0	0	2	0	0	0	0	0	0	5.3
43	17	49	6	2	26	22	33	39	19
100	88.9	94	100	100	86.7	95.5	85	91.7	89.5
57	18	50	5	1	30	22	40	36	19
16.3	21.4	15.7	14.3	0	0	23.5	5.6	22.5	31.3
43	14	51	49	6	23	17	36	40	16

While beneficial to include as many traits as possible, when using the mean measure of divergence statistic; it is problematic to use traits that are correlated. Thus, traits were compared pairwise using Kendall's tau_*b* to determine if any problematic correlations existed. High correlations (e.g., 0.6 and higher) can skew the results of the MMD statistic (Sjvøld, 1977; Irish, 1998b); that is, values are artificially inflated (Harris and Sjvøld, 2004). Kendall's tau-b is a conservative measure, meaning that it is more likely to find correlated traits, resulting in more traits being removed from analysis (Irish, 2010). Four traits were found to be highly correlated at 0.6 or greater. MMD scores were calculated once with the four correlated traits included and once with them omitted (Table 11). The four traits are: labial curvature, deflecting wrinkle, C1-C2 crest, and protostylid. As there were differences, as seen in table 11, only the MMD comparisons with the four traits removed will be discussed further.

The MMD is a measure of dissimilarity between pairs; therefore if a pair has a high value the statistic suggests greater phenetic dissimilarity and vice versa (Irish, 2005, 2010). The MMD was used in conjunction with the Freeman and Tukey angular transformation to adjust for small sample sizes (less than or equal to 10) and for high and low frequency traits (Sjøvold, 1977; Green and Suchey, 1976). To determine if the MMD value represents a significant difference it has to be greater than two times the standard deviation and the null hypothesis is rejected at the 0.025 level (Sjøvold, 1977; Irish, 2005, 2010).

Table 11. MMD values. The asterisks mark values that indicate a significant difference between a pair of sites.

Site	Bolores MMD with 4 traits	Bolores MMD without 4 traits	Feteira II MMD with 4 traits	Feteira II MMD without 4 traits
ABY	0.059	*0.159	*0.132	*0.189
BED	0.023	*0.11	*0.18	*0.263
BOL	0	0	0	0.037
CAP	0	0.06	*0.14	*0.26
FET	0	0.037	0	0
GRK	0.084	*0.147	*0.2	*0.234
HRK	*0.069	*0.149	*0.182	*0.245
ITY	0.059	*0.179	*0.162	*0.268
KAB	0.001	*0.119	*0.116	*0.189
KER	*0.135	*0.327	*0.207	*0.366
LCB	0.005	0.051	0.086	0.141
LCI	0.066	*0.107	*0.134	*0.163
SAQ	*0.167	*0.293	*0.27	*0.393
SHA	0	*0.16	*0.147	*0.284
TAR	*0.149	*0.329	*0.201	*0.322
THE	*0.092	*0.242	*0.174	*0.296
TRK	0.085	*0.189	*0.137	*0.24

Using MMD values with the highly correlated traits excluded from analysis, Feteira II (0.037) and Bolores (0.037) are not significantly different. Bolores is also similar to the Capsian (0.06) and Lachish Bronze Age (0.051) samples, and Feteira II is similar to the Lachish Bronze Age (0.141) sample. The remainder of the comparisons with the Bolores and Feteira II individuals, as seen in Table 17, yield significant differences.

To determine the relationship between phenetic distance and geographic distance correlations were calculated between the MMD values and actual geographic distance (km) between samples. The Pearson's R correlation coefficient revealed a significant positive correlation between phenetic distance and geographic distance when comparing

Bolores (0.628) (p=0.007) and Feteira II (0.514) (p=0.035). This conclusion fits the stepping stone isolation-by-distance model discussed in chapter 5. Positive relationships are represented in both scatter plots (Table 12) (Figure 6, 7).

Table 12. The results from the Pearson's R correlation coefficient

Sites	Pearson's R Value	Approximate Significance
Feteira II	0.514	0.035
Bolores	0.628	0.007

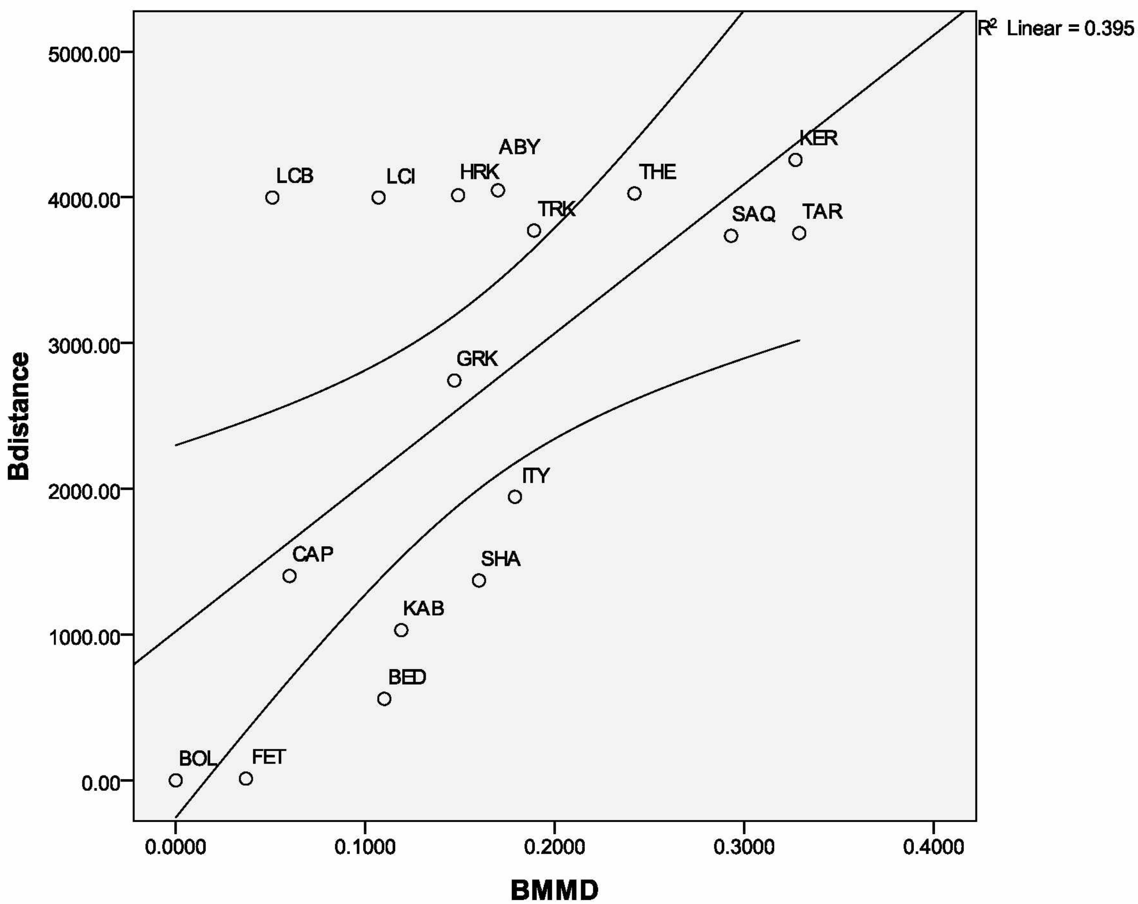


Figure 6. Scatterplot of Bolores distance (km) versus MMD values.

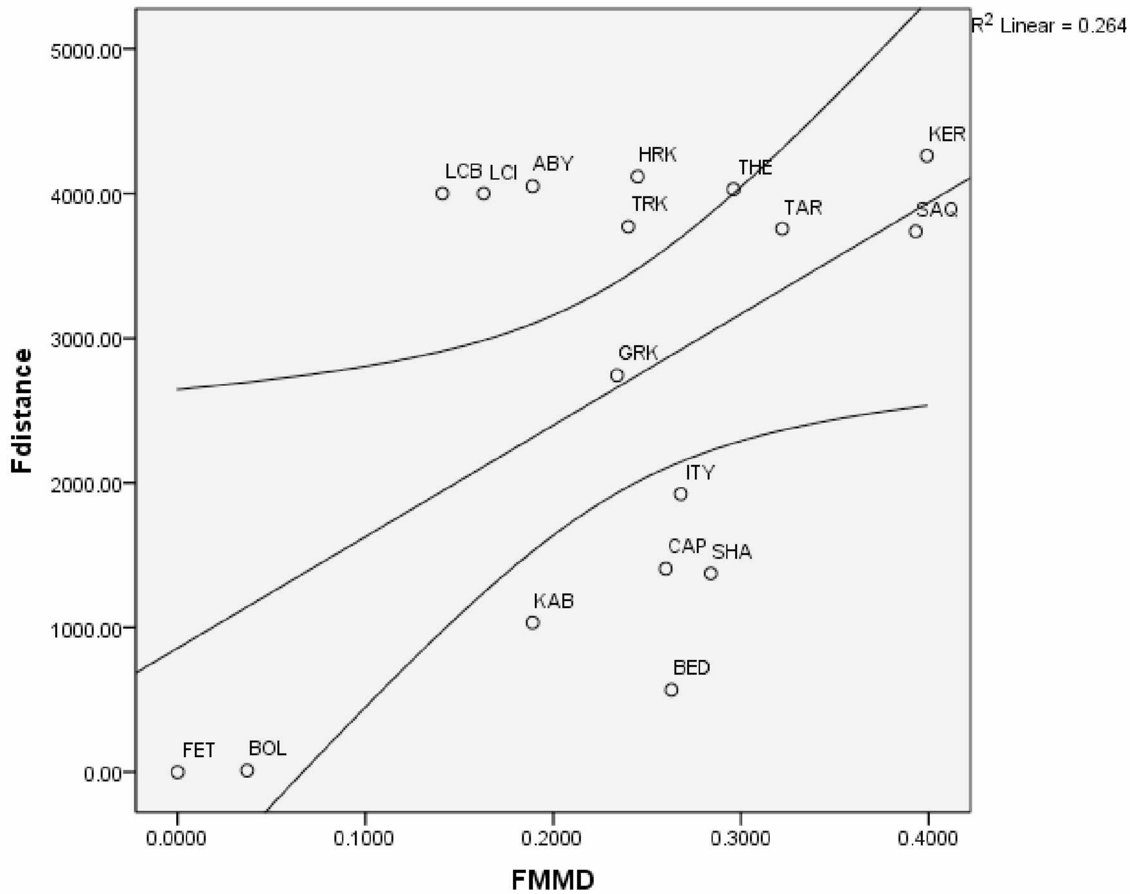


Figure 7. Scatterplot of Feteira II distance (km) versus MMD values.

There is a significant positive correlation between geography and phenetic distance. When contrasting Bolores with the comparative samples, Capsian, Greek, Thebes, Saqqara, Kerma, and Tarkhan, all fall with the 95% confidence interval. Italy,Turkey, and Feteira II are close to the 95% confidence interval (Figure 5). In other words, these groups fit the isolation by distance stepping stone model, meaning that the farther they are away geographically (km) the more different they are phonetically. This does not mean that the groups are not exchanging genes; rather, that limited gene flow is occurring along a continuum with neighboring groups (Wright 1938, 1940, 1943; Kimura and Weiss, 1964; Konigsberg, 1990). , These relationships are heuristically demonstrated in the maps in figures 8, 9, 10, and 11. These “star maps”, as defined by Christy Turner II (Turner, 1995; Guatelli-Steinberg et al., 2001, Irish, personal communication, 2012), are representative of the relationship between MMD values and geographic distance (Figure 6, 7, 9, 10). The shorter lines mean that the sites are phenetically closer than geographically close; longer lines mean that sites are farther away phenetically than geographically; lastly, lines that directly meet the sites demonstrate that the relationship perfectly fits the model. The lines represent MMD values that have been made into a proportion of the geographic distance and then plotted in km.

A number of groups do not fit the isolation-by-distance stepping stone model: Bedouin, Kabyle, Shawia, Lachish Iron Age, Heirakonpolis, and Abydos, and Lachish Bronze Age. The Lachish (n=34) sample is small, with many missing data, because of this, it is more likely to artificially look like other samples; it does not have enough evidence to differentiate itself (Irish, personal communication, 2012). The northwest African samples Capsian, Bedouin, Kablye, and Shawia appear to be close to Bolores in phenetic and geographic distance (Figure 8, 9). This relationship could provide evidence for a connection between North Africa and Portugal. Heirakonpolis and Abydos do not fit the model; they appear to be closer phenetically then they are geographically. This relationship seems to suggest possible gene flow between Egypt and Portugal; the consequences of this relationship will be discussed in detail below.

When the relationship between geographic distance and phenetic distance for Feteira II are compared the general groupings stay the same as Bolores; however, the phenetic distance increases (Figure 5, 6). The samples from Bolores, Greek, Thebes, Tarkhan, Kerma, and Saqqara all fit the isolation-by-distance stepping stone model and fall within the 95% confidence interval, and Italy and Turkey both approach the 95% confidence interval. The northwest African samples (Kabyle, Bedouin, Capsian, and Shawia) cluster together; Heirakonpolis, Lachish Iron Age, Lachish Bronze Age, and Abydos do not fit the isolation-by-distance stepping stone model. Because these relationships are generally similar to Bolores a detailed discussion will continue below combining interpretation when possible.

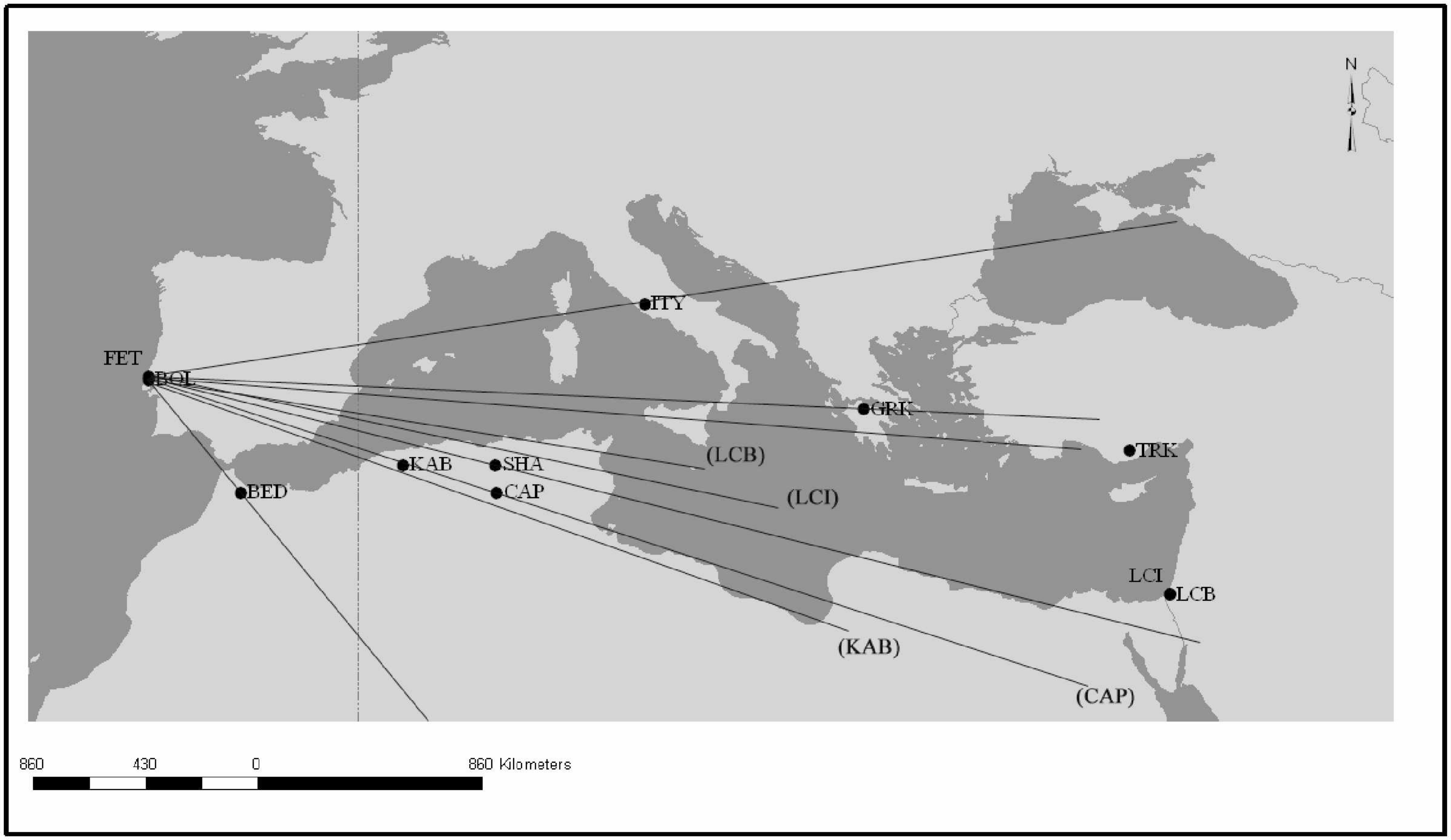


Figure 8. Feteira II MMD star map of Mediterranean samples.

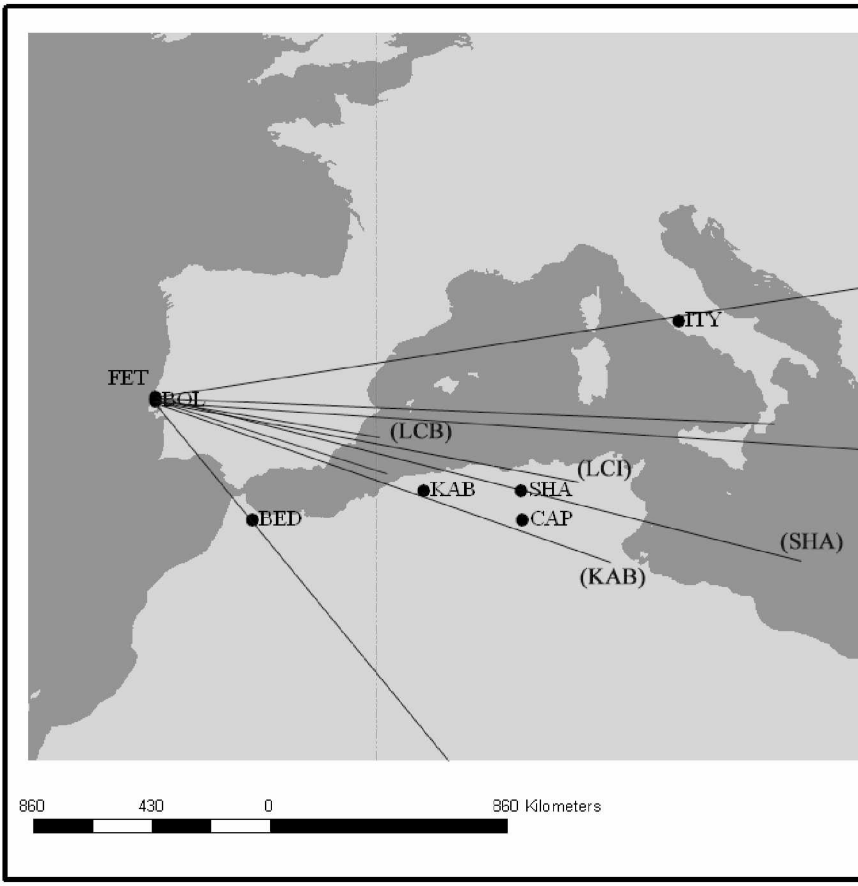
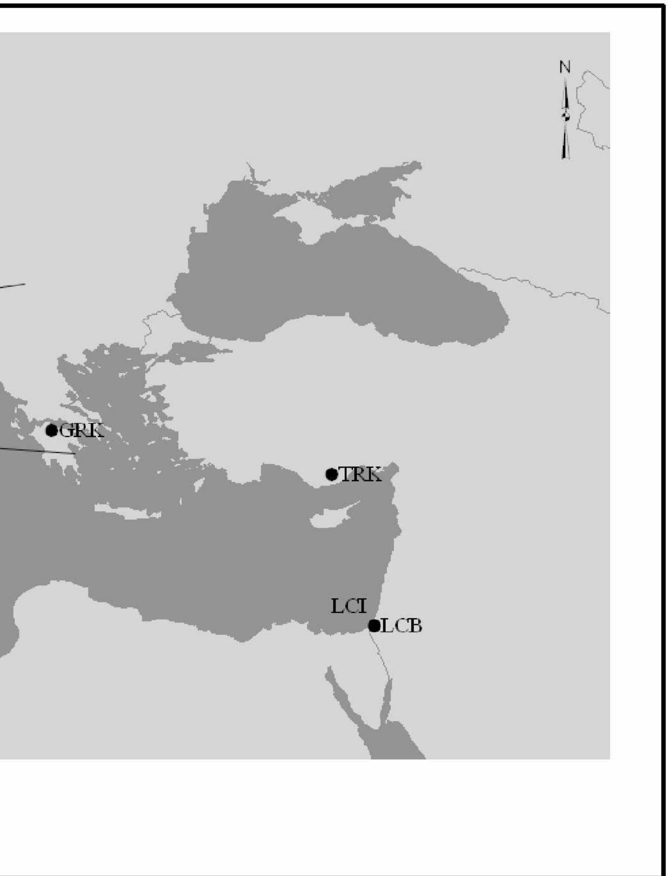


Figure 9. Bolores MMD star map of Mediterranean samples.



N
GRK
TRK
LCI
LCB

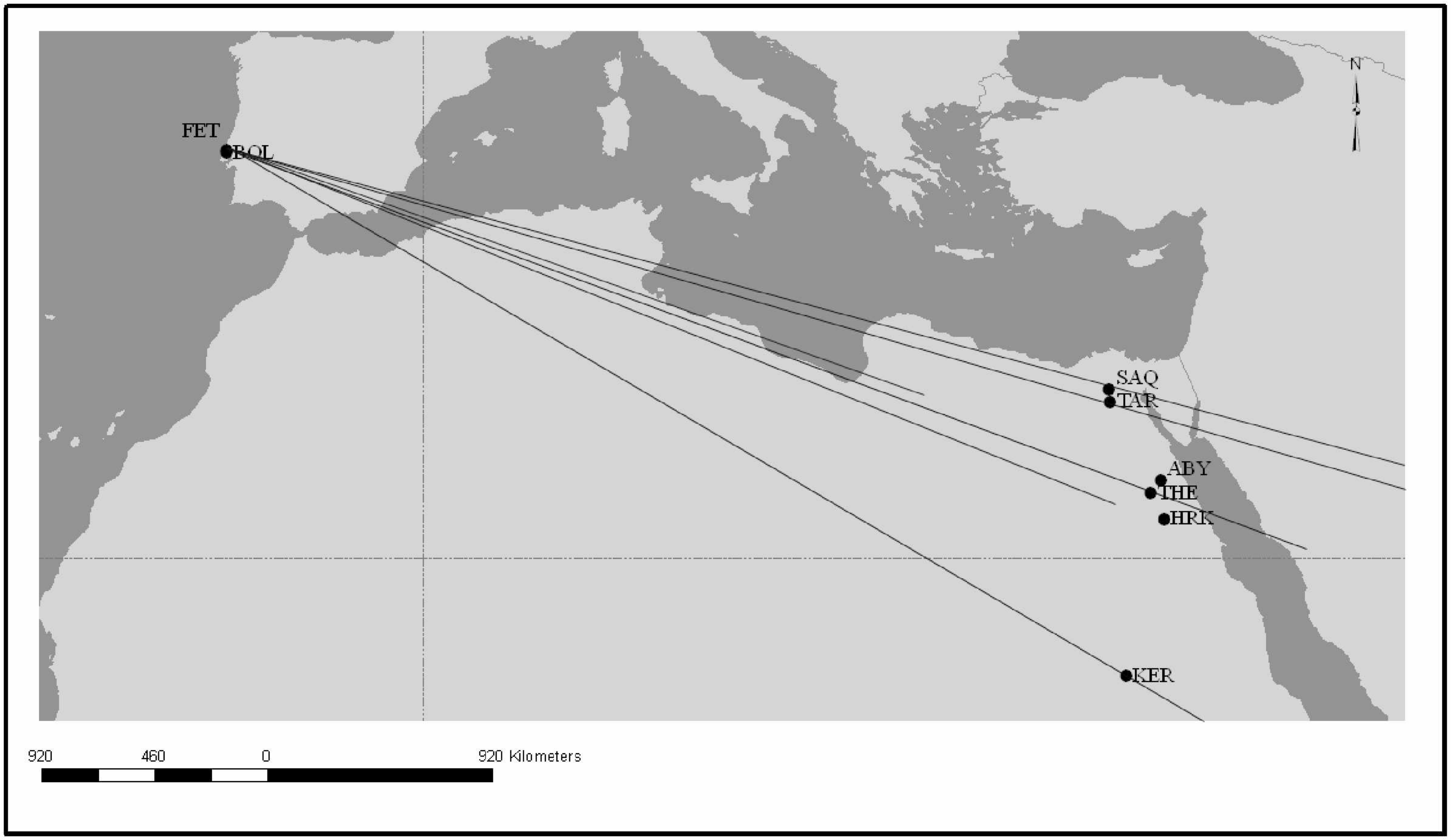


Figure 10. Feteira II MMD star map compared to Egyptian and Nubian samples.

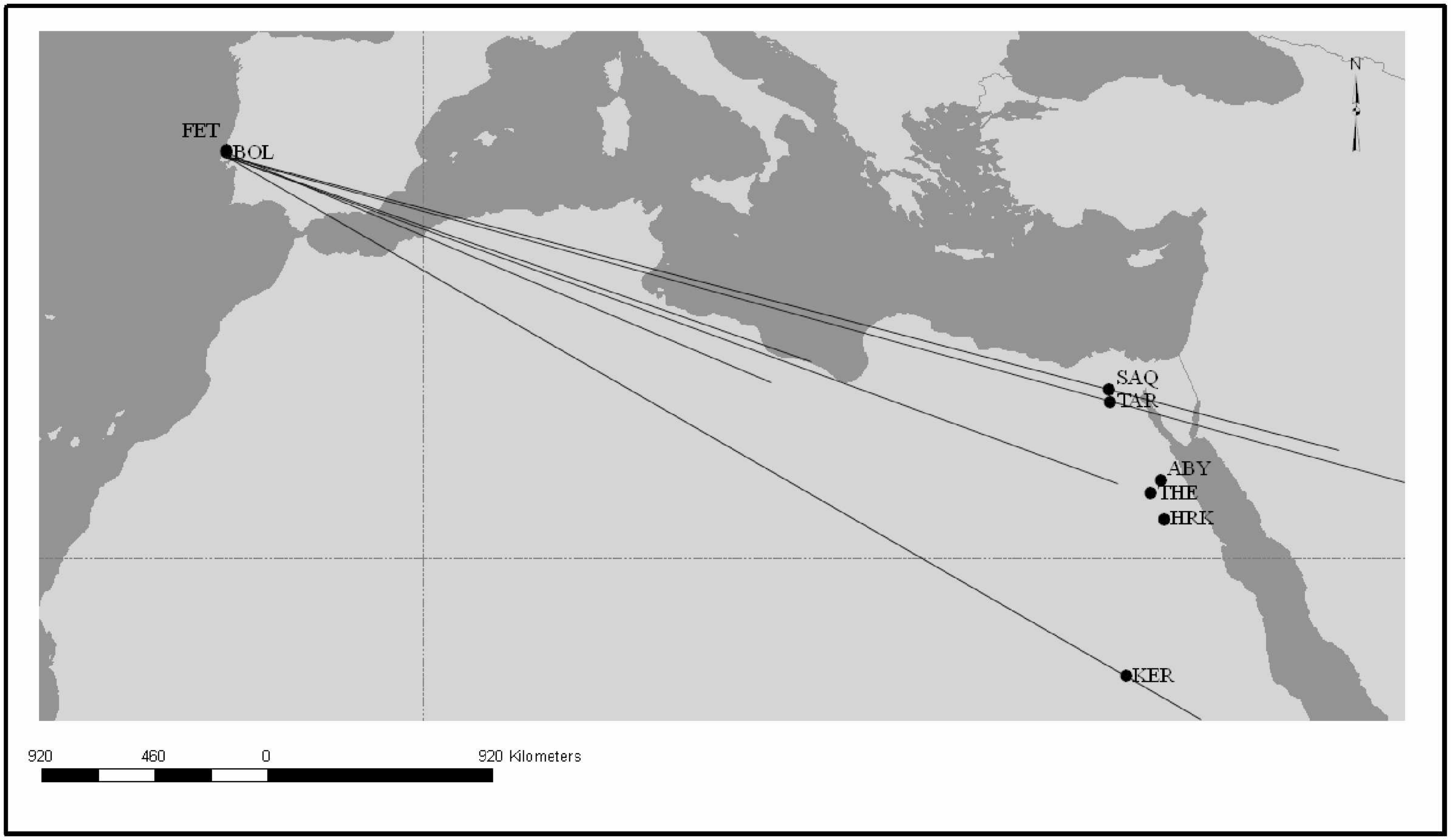


Figure 11. Bolores MMD star map compared to Egyptian and Nubian samples.

CHAPTER 7

DISSCUSION

Microwear

Independent samples t-tests indicated that there are no significant differences between Feteira II and Bolores in the type and occurrence of microwear features. Features compared were percentage of pits and scratches, tally of pits and scratches, pit width in microns, and striation breadth and length in microns.

Were there dietary differences between Feteira II (3600-2900 B.C.E.) and Bolores (2800-1800 B.C.E)? A number of social changes were affecting the Estremadura during this time frame, as discussed in chapter 2, the most influential being: the appearance of Bell Beaker ceramics and a steady increase in social complexity as evidenced by large fortified settlements and social stratification in burials (Jorge, 2003; Lillios, 2004). When taking into account the other information known about Feteira II and Bolores there are some interesting points to be considered:

1. Caries rates do not increase significantly through time when observing Feteira II and Bolores with other sites in the region (Waterman, 2006; Lillios et al., 2010).
2. Isotopic evidence demonstrates a reliance on C^3 plants and terrestrial proteins for individuals from both Bolores and Feteira II; however, at Feteira II there is more dietary variability and evidence that some individuals may have been consuming some C^4 plants, terrestrial and marine resources (Lillios et al., 2010; Waterman, 2012).

3. As observed here scratches, as opposed to pits, dominate when observing microwear features.

Caries rates in Feteira II and Bolores are generally high when compared to other groups globally. Caries rates compared within the Estremadura region are varied, suggesting a dietary variability from the Middle Neolithic through Early Bronze Age. More specifically, a between site comparison reveals that Feteira II and Bolores samples have similar caries rates suggesting that there is no change in these rates as social complexity increased (Waterman, 2006; Lillios et al., 2010).

Teeth from Feteira II and Bolores exhibit similar wear patterns and attrition rates, including cupping wear that is characteristic of agricultural populations and tied to the consumption of soft food with the inclusion of grit (Waterman, 2006; Waterman and Horwath, 2009; Smith, 1984). In highly worn mandibular molars, there is a pronounced lingual to buccal slope and in maxillary molars a buccal to lingual slope. This pattern suggests a reverse curve of Monson which may indicate abrasives in the diet connected to milled grains or sand from seafood (Waterman and Horwath, 2009). Macrowear comparisons between these groups suggests that there was not an observable dietary change between Feteira II and Bolores (Waterman and Horwath, 2009).

Isotopic evidence for the site of Bolores indicates a reliance on C3 plants and terrestrial protein that seems to rule out seafood in the diet even with the proximity of a river estuary and the Atlantic Coast to this site. Of the four individual's examined with stable isotope analysis, one sub-adult was slightly divergent from the others; however, this individual still fell within the C3 plants and terrestrial protein range (Lillios et al., 2010). Isotopic evidence for Feteira II suggests that C3 plants and terrestrial proteins were a major component of diet and there is also evidence to suggest the minor inclusion of fresh and/or salt water fish and C4 plants such as millet or seaweed (Waterman, 2012). Isotope analysis indicates some variability between the diets of individuals interred at Feteira II and Bolores.

Human dietary reconstruction requires not only knowledge about frequency of dietary features, but also any other information known about diet in the groups studied. From the above discussion there are several things that can be inferred about diet in Feteira II and Bolores individuals:

1. Caries rates are low, suggesting that even though agriculture was in full swing there was not a singular reliance on high-sugar carbohydrates (Waterman, 2006; Lillios et al., 2010).
2. Cupped wear that is evidence of soft food consumption with grit and is correlated with agricultural groups and a reverse curve of monson that is related to consumption of foods with grit are both present (Waterman and Horwath, 2009).
3. Isotope analysis reveals that there is slight variability between the diets of Feteira II and Bolores (Lillios et al., 2010; Waterman, 2012).

Pits and scratches differ between living groups based on dietary differences. Various events influence the formation of microwear features and these events can be used to reconstruct general points about diet. No significant difference was determined between groups for number of scratches; however each group had a higher percentage of scratches than pits. As described in chapter 5, scratches dominate when the dietary texture of food is soft, as well as when sand or grit created by stone tools are present in the diet (Grine, 1987; Schmidt, 2001; Teaford, 1988ab; Ungar and Spencer, 1999; Ungar and Teaford, 1996; Teaford 1986; Teaford and Runestad, 1992; Teaford and Lytle, 1996). This pattern is consistent with the conclusions of Waterman and Horwath (2009) that soft foods and high abrasives were characteristic of the diets in Feteira II and Bolores. If compared to isotopic evidence in Feteira II the high percentage of scratches could indicate the inclusion of sand from marine food sources and in Bolores the high percentage of scratches could be the result of of phytolith rich plant foods or the inclusion of grit from stone processing techniques (Grine, 1987; Schmidt, 2001; Teaford, 1988ab; Ungar and Spencer, 1999; Ungar and Teaford, 1996, Teaford and Lytle, 1996). Evidence from caries suggest that scratches in the Bolores and Feteira II groups could be caused by phytolith rich plant foods or marine resources, because there was not a singular reliance on sugary carbohydrates (Waterman, 2006; Lillios et al., 2010) (Table 13).

Table 13. Summary of the methods used to investigate diet.

Dietary Indicator	Difference between Feteira II and Bolores	Conclusion	Source
Microwear	No significant difference, except between adults and sub-adults for scratch breadth	Soft foods and high abrasives	Present study
Macrowear	No significant difference	Soft foods and high abrasive	Waterman and Horwath, 2009
Caries	No significant difference	No singular reliance on high sugar carbohydrates	Waterman 2006; Lillios et al., 2010
Isotope	Some differences	Bolores-C3 plants and terrestrial proteins Feteira II-C3 and C4 plants and terrestrial and marine proteins	Lillios et al., 2010; Waterman, 2012

Due to the above evidence, the hypothesis that social change resulted in significant dietary change can be rejected. Overall, there is no significant difference between Feteira II and Bolores. Other diet-based evidence supports this conclusion by agreeing directly as is the case of macrowear analysis or showing minor variation in diets such as isotope analysis. There seems to be no evidence that supports that social change resulted in significant dietary change between Feteira II and Bolores; however, isotopic evidence does suggest that through time diet became more homogenous (Lillios et al., 2010; Waterman, 2012).

Biological Affinity

Feteira II and Bolores. Comparing non-metric dental traits using the MMD indicates that individuals at Feteira II are not significantly different from Bolores. This conclusion is in agreement with Jackes et al. (2001) research arguing for continuity from the Mesolithic through the Copper Age in Portugal. Due to this similarity, it is possible to infer that during the Late Neolithic through Early Bronze Age, a time of increasing social complexity and when Bell Beaker pottery emerged, the individuals interred at Feteira II and Bolores were biologically continuous. Put another way, there was no evidence from dental non-metric traits to support wide-scale population replacement during the middle Neolithic through the early Bronze Age in groups interred at Feteira II and Bolores.

Based on the evidence, the hypothesis that there is a significant phenetic difference between the individuals interred at Feteira II and Bolores is rejected. Is there evidence for population change instigated by migrating “Beaker Folk”? Because there is no significant difference between Bolores and Feteira II, there is no evidence of population induced change due to Bell Beaker immigrants, at least between these sites. When compared to the hypotheses put forth by Childe (1957) and Harrison (1980) of colonization and cultural exchange respectively, Feteira II and Bolores fit with Harrison's (1980) model of cultural exchange.

Global MMD Comparisons. How do Feteira II and Bolores compare to other Mediterranean groups? When compared by the MMD statistic, Bolores is similar to Feteira II, Capsian, and Lachish Bronze Age samples. Feteira II is similar to Bolores and Lachish Bronze Age samples. These similarities will be discussed further below in context with the isolation-by-distance stepping stone model.

Isolation-by-Distance Stepping Stone Model. When comparing both Feteira II and Bolores to the Lachish Iron Age sampl (n=365), they are closer phenetically than geographically; this affinity is interesting, because there is no known contact between ancient Palestine and the Estremadura region of Portugal. Lachish Bronze Age is a heterogeneous sample with possible admixture from groups in Egypt, Nubia, and the entire Mediterranean (Dicke-Toupin, 2012); it is possible that because of this admixture Bolores and Feteira II appear to be phenetically similar to Lachish Bronze Age when there is no direct gene flow taking place.

When comparing Feteira II and Bolores to the Abydos and Heirakonpolis samples the relationships are similar: Abydos and Heirakonpolis are phenetically more similar than they are geographically distant. Heirakonpolis (3500-3200 B.C.E) (n=247) and Abydoes (3000-2686 B.C.E) (n=47) are both from Upper Egypt and were found to be similar to one another when compared using the MMD statistic in a previous study by Irish (2006). It is difficult to say why these groups do not fit the isolation-by-distance model. This similarity does not account for a significant amount of gene flow because these groups are significantly different from both Feteira II and Bolores when compared using the MMD statistic. Therefore, any contact between Hierakonpolis and Abydos groups would have been minor.

The Feteira II sample's relationship with the northwest African samples is different from that of Bolores. When comparing genes and geography between Feteira II and northwest Africa, all the northwest African samples are phenetically more distant than they are geographically distant, the opposite is true when comparing the Bolores samples to the northwest African samples. As was discussed early in this thesis, there are northwest African cultural items (e.g. elephant ivory and ostrich egg shells) that appear in the Estremadura region of Portugal during the Late Neolithic/Copper Age as well as Bell Beaker artifacts that appear in northwest Africa during the same period (Gilman and Harrison, 1977; Harrison, 1980, Cardoso, 2000; Schuhmacher et al., 2009). Because these artifacts are present only at the very end of Feteira II's use date, there would be no observable gene flow between the Feteira II sample and the northwest African samples. These artifacts are present during the entire use of the Bolores site; therefore, it is possible that there was gene flow between Bolores and northwest African groups. It is important to keep in mind that Bolores has a small sample size and future work is necessary to determine the validity of this conclusion. While the input of genes from northwest Africa was not significant enough to cause Bolores and Feteira II to be divergent from one another, there seems to be some sort of relationship between Portugal and northwest Africa.

CHAPTER 8

CONCLUSION

The Estremadura region of Portugal during the Middle Neolithic through the Early Bronze Age (3600-1800 B.C.E.) was characterized by a rapid increase in social complexity. By the Copper Age, fortified hilltop settlements were present and archaeological remains from these regions included trade items e.g. Bell Beaker ceramics, as well as, elephant ivory and ostrich egg shells from northwest Africa. To contribute to understanding social change in the region, dental microwear and non-metric dental traits were examined in individuals from the burial sites of Feteira II (Middle to Late Neolithic, 3600-2900 B.C.E.) and Bolores (Late Neolithic through Early Bronze Age, 2800-1800 B.C.E.) to investigate diet and affinity between the sites.

Dental microwear analysis was used to investigate dietary change by comparing microwear features. Many dietary analyses have been carried out on the dental remains from Feteira II and Bolores (Waterman, 2006, 2012; Waterman and Horwath, 2009; Lillios et al., 2010); dental microwear analysis was chosen to contribute to these studies. Microwear features in this study were observed on the x or 10n facet on the mandibular second left molars. Once a micrograph was taken, using the Scanning Electron Microscope, the software program *Microwear 4.02* was used to identify and produce summary statistics for microwear features. Feature tally, scratch length, scratch breadth, percentage of scratch occurrence, pit width, and percentage of pit occurrence were compared between Feteira II and Bolores using the independent samples t-test.

Dental microwear analysis was used to investigate the hypothesis: the period of social change is associated with dietary change between individuals interred at Feteira II and Bolores. This study concluded, by synthesizing all known dietary information (caries, carbon and nitrogen isotopes, and macrowear), that there was no significant difference in diet between Feteira II and Bolores as social complexity increased; however, isotope analysis provides evidence for increase homogeneity in diet over time. Microwear analysis also suggests that diets consisted of soft food with high abrasives. There is no microwear evidence to support that the period of social change experienced by individuals in the Estremadura region was associated with dietary change.

By the Copper Age, there was archaeological evidence of long distance trade in the Estremadura region. Did the increase in social complexity, as described above, and the appearance of these trade items coincide with an influx of new genes/people? The following hypothesis was investigated: individuals interred at Feteira II and Bolores are significantly different phenetically when observing non-metric dental traits. The Arizona State University Dental Anthropology System was used in this thesis to investigate affinity between individuals interred at Feteira II (Middle Neolithic to Late Neolithic) and Bolores (Late Neolithic to Bronze Age). Secondarily, Feteira II and Bolores groups were also compared to other groups in the Mediterranean area to investigate sources of possible gene flow.

Dental morphological traits were collected from human remains from Feteira II and Bolores using the ASUDAS. Trait scores were dichotomized using standard breakpoints and submitted for analysis using the mean measure of divergence statistic.

Using the Arizona State Dental University Anthropology System and supporting statistics determined there was no significant difference between the samples from Feteira II and Bolores based on non-metric dental traits. This similarity indicated two points about the sites 1) there was probably no population replacement between the Late Neolithic and Early Bronze Age, and 2) there is no current evidence that points to population replacement or large-scale change during the Beaker period.

When comparing Feteira II and Bolores groups to groups in the Mediterranean area (Palastine, northwest Africa, Egypt, Nubia, Greece, Italy, and Turkey). The MMD statistic revealed similarities between Bolores and Feteira II, Bolores and Capsian (northwest Africa), Bolores and Lachish Bronze Age (Palestine), and Feteira II and Lachish Bronze Age. To further investigate possible interaction between Feteira II and Bolores with the Mediterranean area, Pearson's R correlation coefficient was calculated between MMD values (phenetic distance) and geographic distance (km). There was a significant positive correlation between phenetic distance and geographic distance. The results from Pearson's R were further interpreted using the Isolation-by-Distance stepping stone model. Feteira II and Bolores, when compared to other Mediterranean and African groups, fit the model. This fit means that phenetic distance and geographic distance are significantly positively correlated. The farther away a sample was from Bolores and Feteira II, the more different they were phenetically.

When observing the relationship between phenetic distance and geographic distance using scatter plots and heuristic star maps there were a few groups that did not fit the model. Bolores and Feteira II and Lachish Bronze and Iron Age samples were phenetically more similar than different. The Lachish groups are highly heterogeneous with possible admixture from groups all over the Mediterranean area; therefore, Bolores and Feteira II individuals could resemble Lachish groups when no direct gene flow is taking place. Bolores and Feteira II are phenetically closer than geographically close to Hierakonpolis and Abydos groups (Egypt). These groups are still significantly difference when observed using the MMD statistic; therefore, any potential gene flow would have been minor. The Feteira II group is phenetically more distance from the northwest African groups then Bolores. This pattern seems to suggest interaction between these regions. Archaeological evidence of trade with northwest Africa was scarce during the use of Feteira II as a burial site; however, during the use of Bolores evidence of trade with northwest Africa was abundant. There was no morphological evidence to support the hypothesis that there was a significant difference between individuals at Feteira II and Bolores. This suggests continuity as social complexity increased in the Estremadura regions.

Future Research

This thesis compared two sites to help investigate questions of dietary change and group movements during the middle Neolithic to Early Bronze Age in Portugal. While this research has provided evidence for continuity in both diet and individuals at Feteira II and Bolores, a future study of the entire region and neighboring regions in Iberia, Europe, North Africa, and Egypt could providing more detail about phenetic or genetic relationships.

A study including more samples from the Estremadura and neighboring regions that carried out multiple methods of dietary analysis would be useful. By synthesizing isotope, caries, dental microwear texture, dental macrowear, and archaeological analyses of food remains, specific traits about diets during the Middle Neolithic through the early Bronze Age in Portugal could be determined.

To investigate wide-spread population movement in Portugal, a study including more and larger samples from the Estremadura and neighboring regions would also benefit from further non-metric dental analysis. Other useful analyses would include ancient DNA analysis and strontium isotope analysis in these groups to investigate hypotheses related to population movements in Iberia, North Africa, and Egypt. Synthesizing these methods could provide strong evidence for population dynamics during the Middle Neolithic though Early Bronze Age.

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APPENDIX A

Smith (1984) Description of Occlusal Surface Wear

Molar

0. Missing or cannot be coded
1. Unworn to polished or small facets (no dentin exposure)
2. Moderate cusp removel (blunting). Thinly enameled teeth (Human deciduous molars, chimpanzee molars) may show cusp tip dentin but human permanent molars show no more than one or two pinpoint exposures.
3. Full cusp removal and/or some dentin exposure, pinpoint to moderate.
4. Several large dentin exposures, still descrete.
5. Two dentinal areas coalesced
6. Three dentinal areas coalesced, or four coalesced with enamel island
7. Dentin exposed on entire surface, enamel rim largely intact
8. Severe loss of crown height, breakdown of enamel rim; crown surface takes on shape of roots

APPENDIX B

Molnar (1971) Wear Plane Types

1. Natural form
2. Oblique (buccal-lingual direction)
3. Oblique (lingual-buccal direction)
4. Oblique (mesial-distal direction)
5. Oblique (distal-mesial direction)
6. Horizontal (perpendicular to the long axis of the tooth)
7. Rounded (buccal-lingual direction)

APPENDIX C

Arizona State University Dental Anthropology System Scoring (Turner et al., 1991)

Winging

1. *Bilateral Winging:* Central incisors are rotated mesiolingually, giving a V-shaped appearance when viewed from the occlusal surface. When the angle formed is greater than 20 degrees, it is classed as 1A; when less than 20 degrees, 1B.
2. *Unilateral Winging:* Only one of the incisors is rotated. The other is straight. No subclasses are recognized.
3. *Straight:* Both teeth form a straight labial surface, or follow the curvature of the dental arcade.
4. *Counter*-winging: One or both teeth are rotated distolingually.

Shoveling

0. *None:* Lingual surface is essentially flat.
1. *Faint:* Very slight elevations of mesial and distal aspects of lingual surface can be seen and palpated.
2. *Trace:* Elevations are easily seen. This grade is probably considered minimal expression by most observers.
3. *Semishovel:* Stronger ridging is present and there is a tendency for ridge convergence at the cingulum.
4. *Semishovel:* Convergence and ridging are stronger that in grade 3.
5. *Shovel:* Strong development of ridges, which almost contact at the cingulum.

6. *Marked Shovel:* Strongest development. Mesial and distal lingual ridges are sometimes in contact at the cingulum.
7. *(UI2 only) Barrel:* Expression exceeds grade 6. To be considered barrel-shaped, the form should not result from a hypertrophied tuberculum dentale.

Labial Convexity

0. Labial surface is flat.
1. Labial surface exhibits trace convexity.
2. Labial surface exhibits weak convexity.
3. Labial surface exhibits moderate convexity.
4. Labial surface exhibits pronounced convexity.

Double-shoveling

0. *None:* Labial surface is smooth.
1. *Faint:* Mesial and distal ridging can be seen in strong contrasting light. Distal ridge may be absent in this and stronger grades.
2. *Trace:* Ridging is more easily seen and palpated.
3. *Semi-double-shovel:* Ridging can be readily palpated.
4. *Double-shovel:* Ridging is pronounced on at least one-half of the total crown height.
5. *Pronounced double-shovel:* Ridging is very prominent and may occur from the oclussal surface to the crown-root junction.
6. *Extreme double-shovel.*

Interruption Groove

0. None. The mesial, distal, and medial areas of the lingual surface of the incisor are smooth, continuous, and not disrupted by any vertical to near-horizontal groove.

M. An interruption groove occurs on the mesiolingual border.

D. An interruption groove occurs on the distolingual border.

MD. Grooves occur on both the mesio- and distolingual borders.

Med. A groove occurs in the medial area of the cingulum

Tuberculum Dentale

0. No expression. Cingular region of the lingual surface is smooth. Ignore any shoveling presence.
1. Faint ridging. Matches grade 1 of the ASU UI1 t.d. plaque.
2. Trace ridging. Matches grade 2 of the ASU UI1 t.d. plaque.
3. Strong ridging. Matches grade 3 of the ASU UI1 t.d. plaque.
4. Pronounced ridging. Matches grade 4 of the ASU UI1 t.d. plaque.

5-. A weakly developed cuspule is attached to either the mesio- or disto-lingual marginal ridge. Cuspule apex is not free. Not represented on a plaque. Interpolated between ASU UI1 t.d. grade 4 and the tuberculum dentale found on ASU UC DAR grade 4.

5. Weakly developed cuspule with a free apex. Size corresponds approximately with ASU UC DAR grade 4 tubuerculum dentale.

6. Strong cusp with a free apex. Size is equal to or greater than the ASU UC DAR grade 5 tuberculum dentale.

Canine Mesial Ridge

0. Mesial and distal lingual ridges are the same size. Neither is attached to the tuberculum dentale if present.
1. Mesiolingual ridge is larger than the distolingual, and is weakly attached tohe tuberculum dentale.
2. Mesmiolingual ridge is larger tan the distolingual, and is moderately attached to the tuberculum dentale.
3. Morris' type form. Mesiolingual ridge is much larger than the distolingual, and is fully incorporated into the tuberculum dentale.

Canine Distal Accessory Ridge

0. Distal accessory ridge is absent.
1. Distal accessory ridge is very faint. (No example of grade 1 appears on the UC plaque, interpolation required.)
2. Distal accessory ridge is weakly developed.
3. Distal accessory ridge is moderately developed.
4. Distal accessory ridge is strongly developed.
5. Distal accessory ridge is very pronounced.

Premolar Mesial and Distal Accessory Cusps

0. No accessory cusps occur.
1. Mesial and/or distal accessory cusps are present.

Tricusped Premolars

0. Extra distal cusp (*hypocone)* is absent.
1. Hypocone is present. Its size equals that of the normal lingual cusp.

Distosagittal Ridge

0. Normal premolar form occurs.
1. Distosagittal ridge is present

Metacone

0. Metacone is absent.
1. An attached ridge is present at the metacone site, but there is no free apex.
2. A faint cuspule with a free apex is present.
3. Weak cusp is present.

3.5 An intermediate-sized cusp is present (Not shown on plaque, interpolation necessary).

4. Metacone is large
5. Metacone is very large (equal in size to a large M1 hypocone)

Hypocone

0. No hypocone. Site is smooth.
1. Faint ridging present at the site.
2. Faint cuspule present.
3. Small cusp present

3.5.Moderate-sized cusp present.

4. Large cusp present.
5. Very large cusp present

Cusp 5 (Metaconule)

0. Site of cusp 5 is smooth, there being only a single distal groove present separating cusps 3 and 4.
1. Faint cuspule is present.
2. Trace cuspule is present.
3. Small cuspule is present.
4. Small cusp present.
5. Medium-sized cusp present.

Carabelli's Trait

0. The mesiolingual aspect of cusp 1 is smooth.
1. A groove is present.
2. A pit is present.

3. A small Y-shaped depression is present.
4. A large Y-shaped depression is present.
5. A small cusp without a free apex occurs. The distal border of the cusp does not contact the lingual groove separating cusps 1 and 4.
6. A medium-sized cusp with an attached apex making contact with the medial lingual groove is present.
7. A large free cusp is present.

Parastyle

0. The buccal surfaces of cusps 2 and 3 are smooth.
1. A pit is present in or near the buccal groove between cusps 2 and 3.
2. A small cusp with an attached apex is present.
3. A medium-sized cusp with a free apex is present.
4. A large cusp with a free apex is present.
5. A very large cusp with a free apex is present. This form usually involves the buccal surface of both cusps 2 and 3.
6. An effectively free peg-shaped crown attached to the root of the third molar is present. This condition is extremely rare, and is not shown on the plaque.

Enamel Extensions

0. Enamel border is straight or rarely curved towards the crown. Score any extension *not* attached to the crown as absent.

1. A faint, approximately, generally 1.0-mm-long extension projecting toward and along the root.
2. A medium-sized, approximately 2.0-mm-long extension.
3. A lengthy extension, generally >4.0 mm in length is present. It may extend all the way to the root bifurcation on molar teeth.

Premolar Root Number

1. *One root:* Tip may be bifurcated.
2. *Two roots:* Separate roots must be greater than one-quarter to one-third of the total root length.
3. *Three roots:* Length defined as in grade 2.

Upper Molar Root Number

1. *One root:* Tip may be bifurcated with deeply inset developmental grooves.
2. *Two roots:* Separate roots are greater than one-quarter to one-third of the total root length. Length determination should take into account bending which is common on third molars.
3. *Three roots:* Length defined as in grade 2.
4. *Four roots:* Length defined as in grade 2.

Radical Number

1. *One radical:* No developmental grooves.

2. *Two radicals:* Two developmental grooves or two round roots with no developmental grooves and one root with two developmental grooves.
3. *Three radicals:* Three developmental grooves or one round root with no developmental grooves or one round root with no developmental groves and one root with two developmental grooves.
4. *Four radicals:* Continuation of above with various root numbers and developmental groove combinations.
5. *Five radicals:* Continuation of above.
6. *Six radicals:* Continuation of above.
7. *Seven radicals:* Continuation of above.
8. *Eight radicals:* Continuation of above.

Peg-Shaped Incisor

0. Normal sized incisor.
1. Incisor reduced in size, but having normal crown form.
2. Peg-shaped incisor as defined above.

Peg-Shaped Molar

0. Full-sized crown with normal third molar morphology.
1. Molar reduced in sized to 7- to 10-mm buccolingual diameter. Form is near normal or somewhat “shriveled”.

2. Molar is <7mm in buccolingual diameter. Crown is peg or cone-shaped with rarely more than two rounded cusps lacking any secondary morphology. Root is simple and single.

Odontome

0. Odontome not present.
1. Odontome present.

Congenital Absence

0. Tooth is present. Any degree of visible impaction is considered as present.
1. Tooth is congenitally absent. No sign of tooth.

Premolar lingual Cusp Variation

A. *No lingual cusp:* A ridge may be present that suggests a much reduced structure without a free tip, but it is scored as cusp absent. Grade A was added after plaque production began when it was realized that lingual cusps can be absent.

0. *One lingual cusp:* Size and form may vary a great deal but tip can be seen.
1. *One or two lingual cusps:* This indecisive class should not be used for worn teeth. It is better to score such teeth as missing data.
2. *Two lingual cusps:* Mesial cusp is much larger than distal cusp.
3. *Two lingual cusps:* Mesial cusp is larger than distal cusp.
4. *Two lingual cusps:* Mesial and distal cusps are equal in size.
5. *Two lingual cusps:* Distal cusp is larger than mesial cusp.

6. *Two lingual cusps:* Distal cusp is much larger than mesial cusp.
7. *Two lingual cusps:* Distal cusp is very much larger than mesial cusp. With wear, this class can be confused with grade 0. When in doubt score individual as missing data.
8. *Three lingual cusps:* Each is about the same size.
9. *Three lingual cusps:* Mesial cusp is much larger than medial and/or distal cusp. With wear, grade 9 can be confused with grade 3. When in doubt, score individual as missing data.

Anterior Fovea

1. Anterior fovea is absent. The sulcus between cusp 1 an 2 continues without interruption from the center of the occlusal surface to the mesial border.
2. A weak ridge connects the mesial aspects of cusp 1 and 2 producing a faint groove.
3. The connecting ridge is larger and the resulting groove deeper than in grade 1.
4. Grove is longer than in grade 2.
5. Groove is very long and mesial ridge is robust.

Groove Pattern

Y. Cusps 2 and 3 are in contact.

+. Cusp 1-4 are in contact.

X. Cusp 1 and 4 are in contact.

Cusp Number

4. Cusp 1-4 (1, protoconid; 2, metaconid; 3, hypoconid; 4, entoconid) are present.
5. Cusp 5 (hypoconulid) is also present.
6. Cusp 6 (Entoconulid) is also present.

Deflecting Wrinkle

0. Deflecting wrinkle is absent. Medial ridge of cusp 2 is straight.
1. Cusp 2 medial ridge is straight, but shows a midpoint constriction.
2. Medial ridge is deflected distally, but does not make contact with cusp 4.
3. Medial ridge is deflected distally forming an L-shaped ridge. The medial ridge contacts cusp 4.

Distal Trigonid Crest

0. *Absent:* Distal border of cusps 1 and 2 are not connected by a crest or loph.
1. *Present:* Distal borders are connected by a ridge.

Protostylid

0. No expression of any sort. Buccal surface is smooth.
1. A pit occurs in the buccal groove.
2. Buccal groove is curved distally.
3. A faint secondary groove extends mesially from the buccal groove.
4. Secondary groove is slightly more pronounced.

5. Secondary groove is stronger and can be easily seen.
6. Secondary groove extends across most of the buccal surface of cusp 1. This is considered a weak or small cusp.
7. A cusp with a free apex occurs.

Cusp 5

0. No occurrence of cusp 5. The molar has only 4 cusps (cusps 1-4).
1. Cusp 5 is present and very small.
2. Cusp 5 is small.
3. Cusp 5 is medium-sized.
4. Cusp 5 is large.
5. Cusp 5 is very large.

Cusp 6.

0. Cusp 6 is absent.
1. Cusp 6 is much smaller than cusp 5.
2. Cusp 6 is smaller than cusp 5.
3. Cusp 6 is equal in size to cusp 5.
4. Cusp 6 is larger than cusp 5.
5. Cusp 6 is much larger than cusp 5.

Cusp 7

0. Nor occurrence of cusp 7.
1. Faint cusp is present. Two weak lingual grooves are present instead of one.

1A. A faint tipless cusp 7 occurs displaced as a bulge on the lingual surface of cusp 2.

2. Cusp 7 is small.
3. Cusp 7 is medium sized.
4. Cusp 7 is large.

Canine Root Number

1. One root.
2. Two roots, free for more than one-quarter to one-third of the total lingual root length.

Tomes' Root

0. Developmental grooving is absent or, if present, shallow with rounded rather than V-shaped indentation.
1. Developmental groove is present and has a shallow V-shaped cross-section.
2. Developmental groove is present and has a moderately deep B-shaped cross section.
3. Developmental groove is present, V shaped, and deep. Groove extends at least one-third of the total root length.
4. Developmental grooving is deeply invaginated on both the mesial and distal borders.

5. Two free roots are present. They are separate for at least one-fourth to one-third of the total root length.

Lower Molar Root Number

1. *One root:* Root tip may be bifurcated. If tips are free for more than one-fourth to one-third of the total root length, score as two roots. The first molar root will usually by U-shaped in crass section with a deep developmental groove in the lingual surface. In the second and third molar roots, a single deep lingual, or deep lingual and buccal developmental grooves can occur.
2. *Two roots:* Two separate roots exist for at least one-fourth to one-third of the total root length. A strong distolingual radical is likely an unattached supernumerary third root.
3. *Three roots:* A third (supernumerary) root is present on the distolingual aspect. It may be very small but is usually about one-third the size of the normal distal root.

Palatine Torus

0. *Torus is absent:* Palate is smooth.
1. *Trace:* Torus is elevated about 1-2 mm.
2. *Medium:* Torus is more extensive, elevated 2-5 mm.
3. *Very marked:* Torus may be 10mm high and 10-20 mm wide. This degree of development is seldom encountered outside of Arctic populations, and even there it is rare.

Mandubular Torus

0. *Absent:* No elevation can be palpated.
1. *Trace:* An elevation can be palpated but not easily seen.
2. *Medium:* Elevation is 2-5mm.
3. *Marked:* Elevation is >5 mm.

Rocker Jaw

0. *Absent:* Lower jaw does not rock back and forth when set on a flat surface because the projections formed by the chin and distal borders of the ascending rami form a tripod.
1. *Almost rocker:* The lower border of the horizontal ramus is sufficiently curved to make the jaw unstable when placed on a flat surface. Such a mandible will rock for about 1 sec.
2. *Rocker:* Horizontal ramus is so convexly curved that the mandible will rock back and forth on a flat surface for several seconds.

Tooth Status

0. No wear. This occurs only in unerupted or erupting teeth.

0-1.Wear facets can be seen with a 10x hand lens on one or more cusps occlusal planes.

1. Dentin is exposed on one or more cusps. Almost always occurs earlier in incisors than in postincisor teeth.

2. Cusps worn off. Incisors are graded as 2 if most of the crown mass is gone.
3. Exposed pulp. Incisor crowns usually worn off.
4. Root stump is functional. All or most of the enamel is worn off.

A. *Antemortem loss:* Socket is partly or fully filled in.

C. *Congenital absence:* This indicator is never used for sub-adults, as defined by third molar eruption or basisphenoid suture closure. A congenital absence score of 1 should be given for those teeth in which that feature is recorded.

I. *Impacted:* Usually third molars or second premolars.

P. *Postmortem loss:* Socket is open and smooth and shows no sign of filling or resorption.

U. *Unerupted:* Tooth is present but unerupted.

Absecessing and Periodontal Disease

None: No identifiable bone loss. Alveolar tooth border is hard and smooth. Root exposure does not exceed 1-3mm dependent on age. Note that supereruption can occur with as much as one- third of the entire root length being exposed without any indication of alveolar bone loss, necrosis, or pocketing.

Pockets: One to three teeth may have localized alveolar bone loss. Pockets vary in size. Remainder of alveolar bone is smooth. Record affected teeth.

Generalized, slight: Periodontal disease affects many teeth with 3-5mm of exposed root plus possible alveolar border pitting. Pockets usually occur as well.

Generalized, medium: There is 4-5 mm of root exposure, alveolar border is usually ragged, and deep pockets can occur.

Generalized, marked: More than 50% of the root is exposed in many teeth. Alveolar border is severely eroded. Pocket depth and form easily grade into the appearance of an abscess. Because bone loss is usually not uniform, generalized amount is estimated on an average state of one or both jaws.

Cultural Treatment

A. *Tooth removal or ablation:* Seldom found in individuals less than 12 years of age. Ablation can be certain if gaps occur or if there is strong differential wear in opposing upper or lower teeth. To be certain that ablation and not trauma is the cause of missing teeth, a population pattern must exist.

B. *Filing:* Teeth may be filed to a point, have their labial surface filed flat or depressed, or be decorated with incised lines. Filed or chipped notches at the tooth corners may occur along other treatment

C. *Staining:* In betel-chewing regions of eastern Asia and Pacific, crania are frequently encountered with red-brown stained teeth. This is unintentional treatment, whereas intentionally black-stained teeth are found in the same region. Use of tobacco stains teth; but it is black-brown in color.

D. *Inlaying:* Cup-shaped holes can be drilled into the enamel of an incisors labial surface followed by the insertion of various decorative materials like gold, pyrite, or turquoise.

E. *Cleaning striations:* Abrasives like pumice mixed with charcoal will scratch enamel. Such cleaning or brushing striations an easily be seen on labial and buccal surfaces with a 10x hand lens. Excessive brushing can leave notches on buccal surfaces with a 10x hand lens. Excessive brushing can leave notches on buccal surfaces usually at the crown-root junction. Toothpick grooves can be found on buccal surfaces, but more often on distal or mesial root surfaces at or near the crown-root junction.

Temporo-mandibular Joint Damage

0. *No damage:* TMJ surface is smooth and unpitted.
1. *Slight*: One-fourth of the TMJ surface is pitted.
2. *Medium*: More than one-fourth but less than one-half of the TM surface is pitted, sometimes deeply so, and sometimes with raised borders.
3. *Severe*: More than one-half of the TMJ area is pitted, eroded, and raised borders may be substantial. Eburnation may be present.
8. Rounded (mesial-distal direction)

APPENDIX D

Descriptions of Dental Morphology Samples

Abydos. This sample (n=54) is located in Upper Egypt and is dated to 3000 – 2686 B.C.E. This group is comprised of Egyptians. This sample was housed at the British Museum of Natural History and Cambridge University (Irish, 2006).

Bedouin Arabs. Bedouin groups, although found in North Africa, originate from West Asian populations. This sample contains 49 individuals: 36 from Morocco, 10 from Algeria, two from Tunisia, and one from Libya. These individuals date to the 19-20th century A.D. and are housed at the University of Minnesota and the Musée de l'Homme (Irish, 2000). Over time they have become admixed with Berber groups, whom they resemble phenetically (Irish, 2000; Guatelli-Steinberg et al., 2001).

Capsian. This north heterogeneous African sample (n=22) (6500-3000 B.C.E) is from the Algerian and Tunisian sites of Mechta el-Arbi, Mechta-Chateaudun, Aïn Dokkara, and Grotte des Hyènes. This sample is housed at the University of Minnesota, the University of Alberta, and the Institute de Paléontologie (Irish, 2000; Guatelli-Steinberg et al., 2001).

Kabyle/Berber. This North African Sample (n=32) from Algiers and Oran region of the Djurdura Mountains of Algeria. This groups is dated to the 19-20th century and is a group with little admixture and this sample is house at the Musée de l'Homme (Guatelli-Steinberg et al., 2001; Irish, 2000).

Shawia/Berber. This sample (n=26) from Algeria is a modern sample and is housed at the Musée de l'Homme. Shawia groups have evidence of admixture from Greek, Roman, Spanish, Turkish, French, and Carthaginian groups (Guatelli-Steinberg et al., 2001; Irish, 2000).

Kerma. The Kerma sample (n=63) is from upper Nubia and dated to 1750-1500 B.C.E.. This group is comprised of C-group Nubians and it housed at Cambridge University (Irish, 2000, 2005).

Saqqara. The Saqqara (n=41) sample is located in Lower Egypt and dated to 2613-2494 B.C.E.. This group is comprised of Egyptians and is housed at the Musée de l'Homme (Irish and Friedman, 2010).

Greek. The Greek sample includes 77 individuals that date to the historic period (475-300 B.C.E.). This is heterogeneous collection from various locations in Greece and Crete and is housed at the American Museum of Natural history (Irish, personal communication, 2012).

Hierakonpolis. The Hierakonpolis sample (n=247) was located in the sites of Hierakonpolis and date to 3500-3200 B.C.E. This ancient city was located on western bank of the Nile River in Egypt. This sample is comprised of Egyptians and is housed at the Hierakonpolis Archaeological Site (Irish, 2006; Irish and Friedman, 2010).

Italy. The Italian sample (n=90) has individuals that date to 30 B.C.E to AD 395 as well as the modern period. The modern and ancient individuals are dentally identical, therefore, they are pooled. This sample is house at the Natural History Musuem, London (Irish, personal communication, 2012).

Tarkan. Tarkan is a sample (n=51) from Lower Egypt dated to 3000-2890 B.C.E. This sample is comprised of Egyptians and is house at Cambridge University (Irish, 2006; Irish and Friedman, 2010).

Kharga. The heterogeneous Kharga sample (n=26) is from Upper Egypt dated to 500-600 A.D. and is housed at the National Museum of Natural History. This group is heterogeneous with possible admixture from Mediterranean groups, Berbers, and Nubians (Irish, 2000, 2006).

Thebes. This sample (n=54) is located in Lower Egypt dated to 2055-1773 B.C.E. (Irish, 2006; Irish and Friedman, 2010). This group is comprised of Egyptians and is located at the American Museum of Natural History.

Turkey. This heterogeneous sample from Turkey and Cyprus (n=40) is comprised of individuals dated to the classic period (~300 B.C.E.) and is housed at the American Museum of Natural History. (Irish, personal communication, 2012).

Lachish Bronze Age. The sample dates to 3300-1098 B.C.E. (n=34) and is located in modern day Israel (Ancient Palestine). This sample is housed at the British Museum of Natural History. This is a small sample and not much is known about this sample except that they belong to the Canaanite culture with Egyptian influence (Dicke-Toupin, 2012).

Lachish Iron Age. This sample (n=365) dates to 1200-520 B.C.E. is located in modern day Israel (Ancient Palestine). This sample is housed at the British Museum of Natural History. The Lachish Iron Age has an Egyptian and Canaanites (Dicke-Toupin, 2012). These individuals come from a large urban city that has been occupied/dominated by Assyrians, Canaanites, Babylonians, and Philistines.